THE BIOLOGY OF POPULATION GROWTH

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THE BIOLOGY OF POPULATION GROWTH

BY

RAYMOND PEARL

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MANUFACTURED IN THE UNITED STATES OF AMERICA

TO

THE MEMORY OF

MY MOTHER

PREFACE

This book is the outcome of a series of investigations upon which I have been engaged for several years past. My first approach to the population problem was purely mathematical. But it immediately became apparent that in its real essence the problem was a biological one. This conclusion led to its controlled experimental study in the laboratory with organisms lower in the evolutionary scale than man. As the work has developed it has also become apparent that a more direct and penetrating study than has hitherto been made of the biological factors underlying human population growth was not only desirable, but absolutely necessary if real progress was to be made. The present volume brings together some of the results along these different lines which have accrued from the studies going forward in my laboratory.

Most of the material in this book is here published for the first time, though I have drawn upon earlier popular and technical papers for parts of Chapters I, VI, and VII.

In the mechanics of the preparation of the book I have departed in some particulars from what is the conventional practice in the arrangement of scientific memoirs. Tables of numerical data constitute in the main the evidence upon which the statements in this book rest. But tables of figures are at best dull reading, and tend sometimes when inserted in the text to annoy the reader. I have, therefore, relegated all numerical data which could be dispensed with in the development of the text to an *Appendix of Tables*. By following consistently a system of cross-referencing from text to table and *vice versa* in each instance, I hope that I have not impaired materially

the usefulness of the book to the serious student who may wish to work with the original tabular data. On the other side, this arrangement will, I am sure, make things much easier and more satisfactory for the general reader.

To the same end I have placed all bibliographic references in a *List of Literature Cited* at the end of the book, numbered them consecutively, and indicated citations in the text by enclosing the ordinal number of the reference in brackets. This plan I believe to be preferable to footnotes, which in the best case certainly detract from the beauty of the printed page, and draw the reader's attention from the text.

Upon advice I have decided, somewhat against my own view as to what is appropriate in the presentation of a piece of scientific research, to translate into English the extracts quoted in the text from writers in other languages (in this case chiefly French). The translations are as literally exact as it is possible to make them. In only two particulars have I deviated from the policy of translating quotations into English. These are, in the first place, when the quotation is very short, involving but a few words of obvious meaning; in the second place, a long quotation from a French writer on technical medical matters among the Arabs would, if literally translated into English, be too frank I fear for a book which will presumably fall into the hands of non-medical readers. In one or two other cases I have left passages in the original language of the writer, for the sake of absolute scientific accuracy in regard to a statistical or other technical point.

Finally, I wish to acknowledge most gratefully the aid I have had in the preparation of this book from my colleagues in the Department of Biometry and Vital Statistics of the School of Hygiene and Public Health of the Johns Hopkins University. In particular am I indebted to Professor Lowell J. Reed, who has been an active collaborator in all the studies

on population which have been made in this laboratory. Also to Professor John Rice Miner, Doctor Mary Gover, and Miss E. Marion Pilpel for aid of various sorts in the preparation of the book. To the Thomas Y. Crowell Company I am very grateful for permission to make a long quotation from Doctor Paul W. Harrison's entertaining and valuable work "The Arab at Home." Similarly I am indebted to Mr. G. Udny Yule, F.R.S., for permission to quote extensively and use illustrations from his address as President of the Royal Statistical Society, and to Dr. O. E. Baker of the United States Department of Agriculture to quote and use illustrative material from a recent important paper of his cited in the bibliography.

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CHAPTER I

HOW THINGS GROW

I

There is at the present moment a great recrudescence of public interest in the problem of population. Books and articles on population growth have been appearing in the last five years with an abandon which could fairly be called reckless if the protagonists were not so obviously in deadly earnest.

To find any parallel to the present interest in population questions one must go back more than a century. During the period from 1890 to 1910 when this country, in common with most of the countries of Europe, was increasing its population by the addition of a larger absolute number of souls *per unit of time* than had ever before been recorded, practically no one thought of discussing the population problem. Rather it was the fashion somewhat to deride Malthus. At the present time, when nearly every civilized country in the world is showing a steadily slowing time-rate as well as a slowing percentage rate of population growth, a great many people are saying something like what Malthus did. The fact that they are talking in about the same way is not particularly remarkable, because from the only premises which existing knowledge a century and a half ago made possible, Malthus reasoned about the future course of population with a logic which was in most respects faultless. The more remarkable thing is that there should be such a wide-spread revival of interest in the subject just now. Why is this?

The answer is that public interest in the question of population appears to be one of the standard consequences of a great

war. The years which linked the dying eighteenth century and the dawning nineteenth marked the end of a period of intensive and extensive warring — Napoleonic in Europe, revolutionary in America. In that period one of the principal topics of serious discussion by thoughtful publicists and statesmen was the population problem. An extensive literature was produced. Indeed with a few extremely scattered and on the whole not particularly penetrating exceptions, it furnished the only bibliographic sources available for the twentieth century student of the problem. The great work was of course that of Malthus, but there were many others of real significance. One of the wisest things Benjamin Franklin's great intellect ever produced was a little essay on "Observations concerning the increase of mankind, peopling of countries, etc., written in Pennsylvania, anno 1751," which in certain respects anticipated the conclusions which Malthus, with more elaborate documentation but no more surely, was later to draw.

The reason why war appears normally to engender concern about population is a two-fold one. In the first place, as Harold Cox in his "The Population Problem" (59) has shown perhaps better than anyone else, population pressure is always a major cause of war, either directly or indirectly. Curiously enough everybody sees this after the event, but apparently never before.

In the second place war always disorganizes, sometimes nearly to disruption, the pre-existing economic structure. The non-combatant population during the war rearranges its affairs in such way as to turn out products of all sorts in greater volume than the whole population, including the combatants, did before the war. The war itself creates the market which absorbs this super-production and indeed clamors for more. But when it ends the combatants come home. They want jobs. But so also do the folks who have stayed at home and

had the jobs. Production all along the line necessarily has to be curtailed, and in consequence unemployment makes its appearance. There comes into existence a more or less vague and inarticulate but wide-spread feeling that there are too many people in the world for the realization of the greatest degree of comfort. And so along another pathway the population problem emerges into the foreground of thought.

Just now, largely for the reasons which have been outlined, the dire menace of ever-growing hordes of human beings variously colored, but invariably pictured as evilly desirous of dominating this pleasant globe, is being exhibited by earnest writers, whose zeal seems at times to outrun their information as well as their discretion. Some years ago it seemed to me perhaps desirable, before sinking miserably into the slough of despond for which we are said to be so inevitably heading, to look dispassionately into the biology of the matter. For plainly all growth, including that of population, is fundamentally a biological matter. It surely can do no harm to investigate the biological laws according to which the thing we are talking about operates. If these can be determined we shall at least know one significant limitation which any proposed social or political solution will have to take into account.

My study of the population problem began in 1920 with an examination of the course of the vital index (birth-death ratio, 100 births/deaths) during and following the war in the chief cities and countries (60, 62). This introduction to the matter led almost immediately to a mathematical attack upon its most fundamental aspect, namely an attempt to determine the law according to which the growth of populations takes place. In this phase of the work my colleague, Professor Lowell J. Reed, has been associated with me from the beginning (61, 71, 75, 76, 78, 79). At the outstart, as a result of applying certain biological reasoning to the problem, we hit upon an equation

to describe the growth of populations, which subsequent work has clearly demonstrated to be a first approximation to the required law. As we were in process of publishing the first discussion of the matter (61) we found that a Belgian mathematician, P. F. Verhulst, (66, 67, 68) had as early as 1838 used this same curve, which he called the "logistic curve," as the expression of the law of population growth. Since that time we have extensively developed and generalized the mathematical theory, and as a result are able to bring under its descriptive power many cases of actual population growth which are not amenable to the simple law first derived by Verhulst. The latest and most complete résumé of the mathematical development of the work is contained in my recent book, "Studies in Human Biology" (27).

At the same time there have been carried on in the laboratory various studies regarding more general aspects of the population problem (63, 64, 65, 69, 70, 72, 73, 74, 77, 80).

It is the object of the present book to bring forward some new and hitherto unpublished evidence, biological, anthropological, and experimental, on the problem. The purpose of this first chapter is to serve as a general introduction and means of orientation, both to the problem itself and to the previous work which has been done upon it in my laboratory. The farther one has gone into the problem the more apparent has it become that the human population question is not to be solved by a study of human material alone, and, particularly of human material derived from the highly civilized and industrialized countries of Western Europe and America. The problem at bottom is clearly a biological one, requiring, to be sure, for its solution the application of appropriate mathematical methods, but also, and of quite as great importance, experimental methods. There begins clearly to emerge the paradoxical situation that probably a real understanding of the

problem to which Malthus addressed himself is going to come more from the intensive study of lower forms of life in the laboratory, under physically and chemically controlled conditions, than from any manipulation of never quite satisfactory demographic statistics.

II

Every living thing starts its separate, individual existence as a single cell. This state is, however, of extremely brief duration. What subsequently happens in the case of a higher multicellular organism, like man say, is that the single cell divides into two, then four, eight, sixteen, and so on to a number which finally becomes uncountably large. But in this process all the cells remain in contact with and attached to each other, the whole mass forming the growing and differentiating individual. This process of growth goes on at different rates, but without interruption or cessation, until the complete development of the adult has been attained. If we measure this process of individual growth by periodically repeated weighings (since counting of the cells is impossible after the very earliest stages) we shall get a rough but sufficiently accurate index of the increase in the number of cells, since they are all of roughly the same order of magnitude.

The results of such periodic weighings give rise, when plotted upon coordinate paper, to a curve of a peculiarly characteristic shape. It is of the form which would be obtained if one first fashioned a letter S out of fairly stiff but flexible wire, and then by grasping the two tip ends partially straightened and stretched the whole thing until the ends of the upper and lower limbs of the letter were practically straight and parallel to a horizontal base, and the curve at the middle of the S had been straightened and inclined to the right instead of the left.

A portion of just such an individual growth curve for the male rat is shown in Fig. 1 (data in Appendix Table 1). The circles are the observed weights. These are taken from Donaldson (81). The smooth curve is the graph of the equation

$$y = 7 + \frac{273}{1 + e^{4.3204 - 7.2196x + 30.0878x^2 - 0.5291x^3}}, \qquad \text{(i)}$$

where y = weight in grams, and x = age in 100-day units. The curve was fitted to the observations by the method described in (27). For further details regarding this and other growth curves for white rats and other forms the reader should consult Pearl and Reed (82).

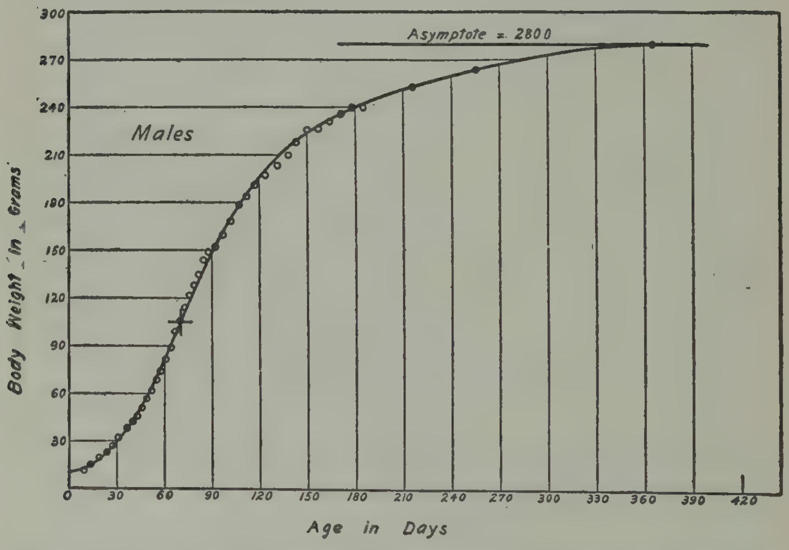

FIG. 1. The curve of growth in body weight of the male white rat. (Observations plotted from data of Dr. H. H. Donaldson). The smooth curve is the graph of equation (i). The cross denotes the point of inflection of the curve.

This stretched-out S shape of the rat growth curve is apparent. This is the characteristic form of the growth curve

of an individual animal or plant brought about by the continued multiplication of cells, which hang together to form what we recognize as the individual. Quite often, as in this case, the curve of growth of an individual is asymmetrical, or skew.

In order that it may be seen that this form of growth curve is in no wise peculiar to the albino rat, two other examples

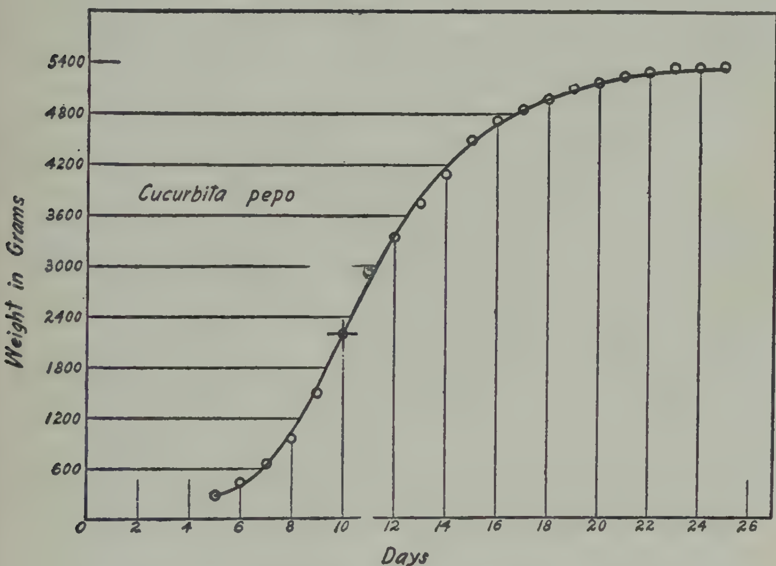

FIG. 2. Growth of *Cucurbita pepo*. (Data from Robertson.)

from the same source (82) will be presented. The first of these concerns the growth of the pumpkin (*Cucurbita pepo*), the data being those of Anderson, taken from Robertson (83), who was the first one to use the simplest symmetrical form of the logistic curve to describe the growth of the individual organism. The data are shown in Fig. 2. The circles give

the observations (which will be found in Appendix Table 2) and the smooth curve is the graph of the following equation:

$$y = 174 + \frac{5190}{1 + e^{10.3148 - 16.3399x + 8.1028x^2 - 1.6667x^3}}, \tag{ii}$$

where y = weight in grams, and x = age in 10-day units.

A third and final example is shown in Fig. 3. It concerns the growth of the tail of the tadpole, after it has been cut off

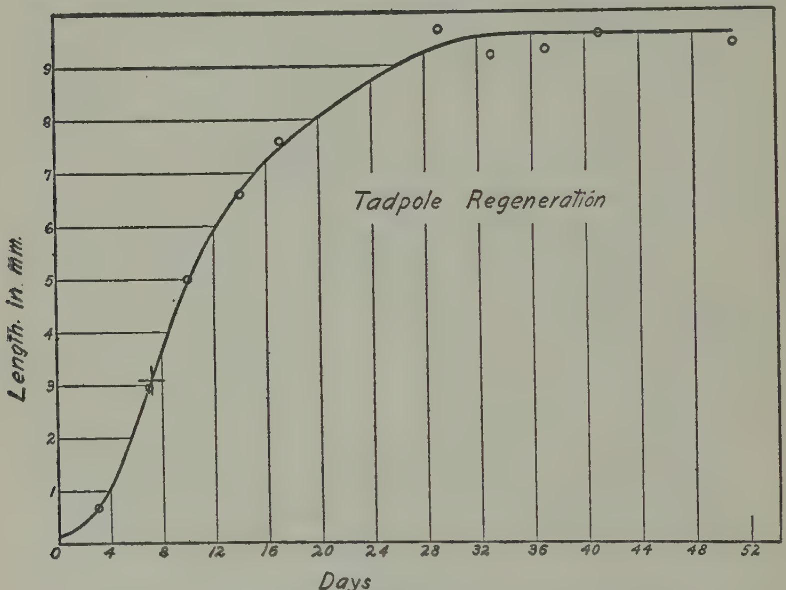

Fig. 3. Regeneration of tadpole's tail. (Durbin's data.)

and is undergoing regeneration. The observations, given by small circles, are from Durbin (84) and are given in Appendix Table 3. The smooth curve is the graph of the equation,

$$y = \frac{9.60}{1 + e^{4.4715 - 7.2829x + 3.3833x^2 - 0.6370x^3}}, \tag{iii}$$

where y = length of regenerated tail in millimeters, and x = age in 10-day units.

It is obvious that in all of these cases the growth follows closely the same general S shaped course given by the skew logistic curve.

Suppose we next consider what happens when a few yeast cells are dropped into an appropriate nutritive solution, saccharine in nature, and the whole kept at a moderately warm temperature. In such a satisfactory environment the initially sown cells quickly divide and re-divide. Here plainly we are

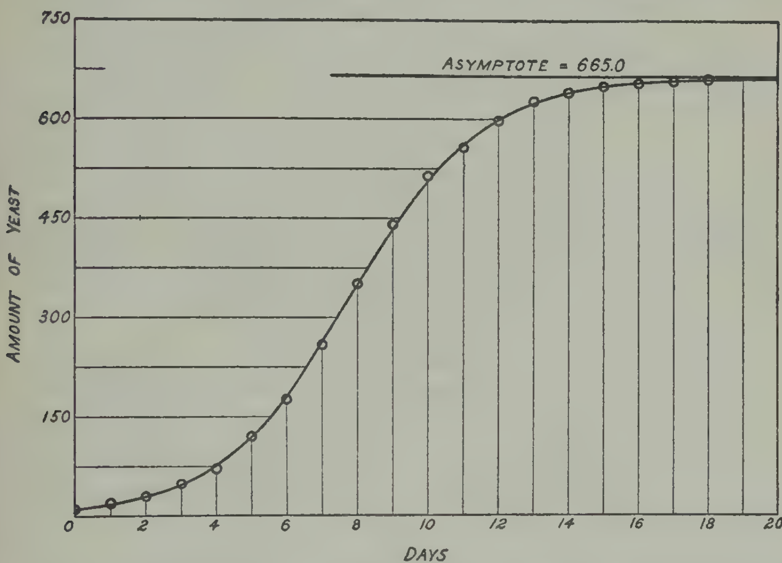

FIG. 4. The growth of a population of yeast cells. Data from Carlson, represented as small circles. Smooth curve from equation (iv).

dealing with the growth of a population — of yeast cells to be sure, but still a population. We can, just as with human beings, take periodic census counts, or their methodological equivalent, and so determine the growth of the population. If such an experiment is tried the result will be essentially like that shown in Fig. 4. The data, given as usual by small

circles, are from the experimental work of Carlson (85). They are shown in detail in Appendix Table 4. The quantity of yeast at intervals in the growth was measured by a method of centrifugation and subsequent determination of volume and mass. So that while the figures in Appendix Table 4 are not actual census counts of the yeast population, they are numbers directly and with a high degree of accuracy proportional to what such counts would have been if they had been taken.

The smooth curve is the graph of equation (iv) fitted to the observations in my laboratory. Carlson himself used a form of the logistic curve to describe this yeast growth.

$$y = \frac{66.5}{1 + e^{4.1896 - 0.5355x}}, \qquad \text{(iv)}$$

where y = quantity of yeast and x = time of growth in days.

It is apparent that this curve for the growth of a simple population of single cells is essentially the same in shape as that which in Figs. 1–3 was seen to describe the growth in size of a single individual multicellular organism. As a matter of fact the same general type of equation describes mathematically the growth in both cases. And this is in no way remarkable, but on the contrary what might reasonably be expected. For biologically the two processes have an important element in common. It is that a major factor in the growth in both cases is the multiplication of cells, by successive division of already existing cells. In the case of the rat, the pumpkin, and the tadpole, all the cells throughout the process stick together to form a single multicellular individual. In the case of the yeast the cells separate after division and each leads its own existence, physically independent of that of all the others. But evidently this is a relatively unimportant distinction, when viewed solely from the standpoint of the mechanics of growth.

In Chapter II we shall go one step farther and examine in detail the growth of population in the case of a multicellular animal of relatively complex organization, in contrast with the simple unicellular yeast plant. We shall see, however, that it follows the same general law in its population growth that yeast does. The animal used in these experimental studies of population growth is the fruit fly *Drosophila melanogaster.*

III

But what has all this to do with human populations and their growth? Such lowly creatures as yeast and flies and rats may be all very well in their place, but they certainly know nothing of such recondite matters as quota plenitude, exclusion of individuals incapable of becoming citizens, and other things which we are accustomed to regard as of enormous importance in determining the growth of human populations. Just how do populations of men grow, as a matter of fact? Do the phenomena here follow a curve of some unique, oddly distorted shape, or the simple S shape curve we have seen?

Sweden has the longest continuous record of census counts of any country. The magnitude of the Swedish population at its several censuses is shown by the small circles in Fig. 5. The original data, taken from (27), are shown as Appendix Table 5. The equation of the logistic curve for Sweden is

$$y = 1.535 + \frac{6.336}{1 + 7.265\, e^{-0.0230x}}, \qquad \text{(v)}$$

In this and the following curves of human population growth y denotes population in millions, and x time.

Now the thing about this diagram which is at once entertaining and instructive is that *the smooth curve is the graph of a mathematical equation of precisely the same sort as that which has been seen to describe population growth in the case*

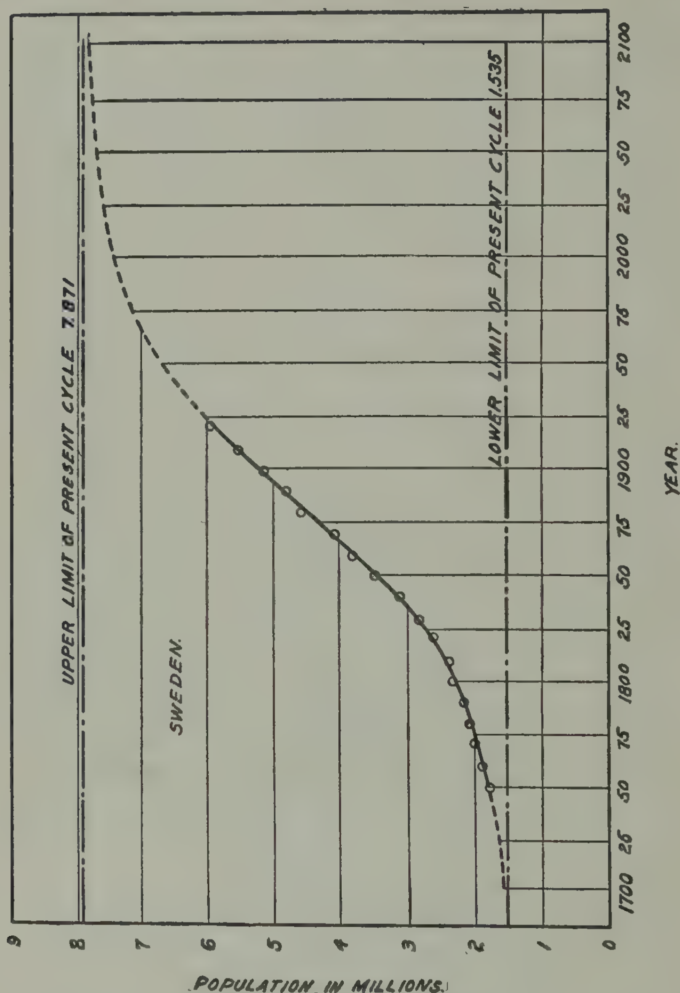

FIG. 5. The population growth of Sweden.

of yeast which we have just discussed. Obviously it fits the human phenomena with extreme accuracy. There appears to be no escape from the conclusion that the population of

Sweden has grown in a manner which, in its quantitative relations at least, is essentially like the manner in which a population of yeast cells grows, or, as will be seen in Chapter II, a population of *Drosophila*.

But Sweden is a small country, whose population has possibly been less disturbed in its growth by migratory movements, war and pestilence, than that of some other countries. One curve does not make a law. What of the United States? Receiving immigrants has been, from the start, one of its chief businesses. From Fig. 6 it is evident, however, that this real and marked politico-social difference between America and Sweden finds no reflection in the manner of growth of the population. Our old friend the stretched-out S curve fits the population history of the United States from 1790 to 1920 with just as great precision as it does that of Sweden from 1750 to 1920. The data on which Fig. 6 is based are given in Appendix Table 6. The equation of the fitted curve for the United States is

$$y = \frac{197.27}{1 + 67.32\, e^{-0.0313x}}, \qquad \text{(vi)}$$

Except for the difference in the amount of time covered by the observations, this curve for the United States is strikingly like that of Sweden. The effect which might have been supposed to appear of "waves of immigration" is most conspicuous by its absence. The reason is that the sole effect of the *net* immigration (that is, number of immigrants less number of emigrants) has been somewhat to steepen the general upward slope of the United States curve, without either altering its fundamental shape or putting irregular waves in its course. It is the normal, natural increase — the steady excess of births over deaths — which fundamentally determines the form of the population growth curve. When any country has

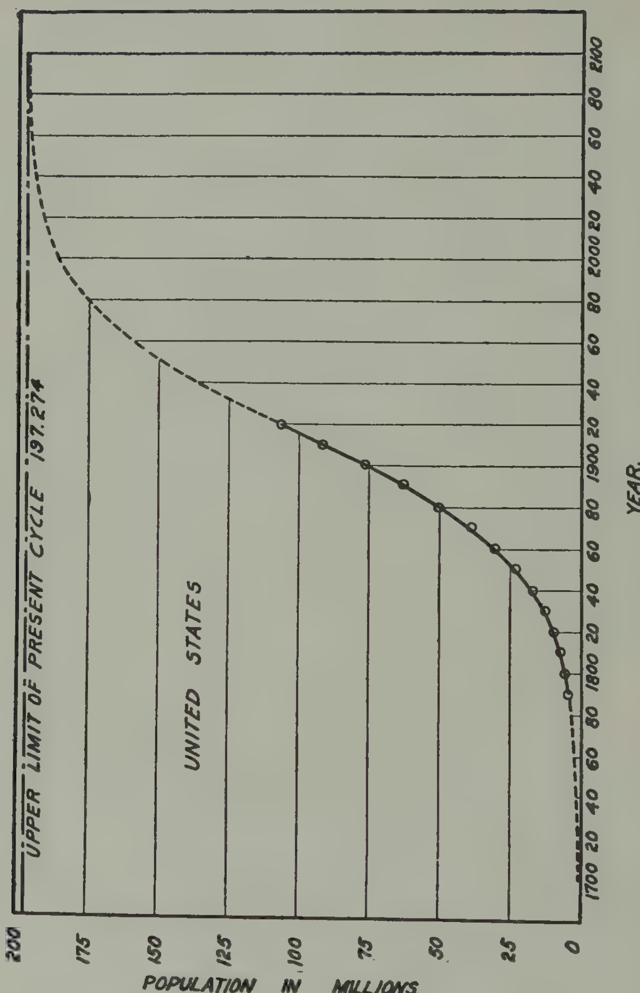

Fig. 6. The population growth of the United States.

a population which is absolutely so large as that of the United States, any normal amount of immigration will not sensibly alter the course of population growth. This curious fact was long ago pointed out by Benjamin Franklin:

"The importation of foreigners into a country that has as many inhabitants as the present employment and provisions for subsistence will bear, will be in the end no increase of people. . . . Nor is it necessary to bring in foreigners to fill up any occasional vacancy in a country; for such a vacancy (if the laws are good), will soon be filled by natural generation."

The French furnish the world's best example of the benefits (or evils, as you like) of a nearly stationary population. Some of them worry about it, others apparently rejoice. At the moment any candidate for political preferment in that country is likely to be called upon to state whether he is for or against babies, just as in America he is confronted with the awkward necessity of declaring himself wet or dry, or evolutionist or fundamentalist.

The known population history of France is depicted in Fig. 7, the small circles again giving the actual census counts, and the smooth curve the fitted mathematical equation. The data for Fig. 7 are set forth in Appendix Table 7. The equation of the logistic curve for France is

$$y = 6.604 + \frac{35.975}{1 + 0.808\, e^{-0.0197x}}, \qquad \text{(vii)}$$

Again we see that, in spite of the fact that all the observed facts (census counts) for France lie at the other end of the growth cycle, still the growth has evidently followed, during the epoch or cycle in which it now is, the same basic law as that of Sweden and the United States.

It begins clearly to appear that the seemingly irrelevant matter about yeast and rats did have some real significance for the human population problem. We have seen that the populations of three countries have followed during their period of recorded census history the same law of growth as

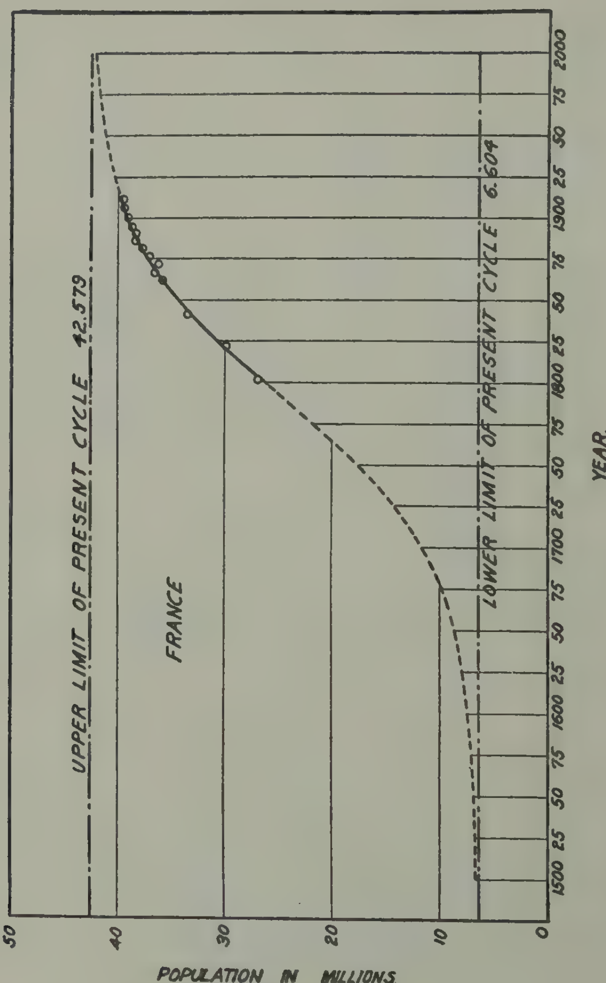

FIG. 7. The population growth of France.

a simple population of yeast cells. In the book "Studies in Human Biology" (27) already referred to, it is shown that the same thing is true of the known population growth of

Austria, Belgium, Denmark, England and Wales, Hungary, Italy, Norway, Scotland, Servia, Japan, Java, Philippine Islands, the world as a whole, and Baltimore City.

In all of these cases of human population which have been found to be amenable to description by the general curve,

$$y = d + \frac{k}{1 + e^{a_1 x + a_2 x^2 + a_3 x^3 \ldots\ldots\ldots a_n x^n}}, \qquad \text{(viii)}$$

the observed population counts cover only a part of the whole range of one cycle of growth. In some countries, as the United States, or England and Wales, it is the earlier part of the cycle for which observations exist. In France it is the late part of the cycle. Sweden comes the nearest of any human population considered up to this time to having observations over the whole cycle. A justifiable inference from all the evidence is that if we had census records over a sufficiently long period of time the theoretical curve would describe human population growth throughout the whole cycle as accurately as it does that of yeast. This remains an inference, however, until a human population presents itself having census records covering an entire cycle of growth. In Chapter III of this book just such a case is described.

In the meantime Fig. 8 is of interest. In this diagram, which is due to the ingenuity of the distinguished English statistician Mr. G. Udny Yule (86), the census data of the three countries England and Wales, the United States, and France have been combined together and a logistic curve fitted by (a) taking the point of inflection of the theoretical curve as origin, (b) taking the limiting population as the unit of numbers, and (c) taking the standard interval as the unit of time. What the diagram shows is that the recorded census histories of these three countries really fall upon different parts of the whole cycle of population growth, but wherever

they fall they follow the course of the theoretical curve at that part of the cycle with great precision. As Yule rightly emphasizes, caution must be exercised against drawing unwarranted conclusions from this Fig. 8. What is really wanted is the census history of the *same* human population throughout a growth cycle, and precisely this case will be discussed in Chapter III.

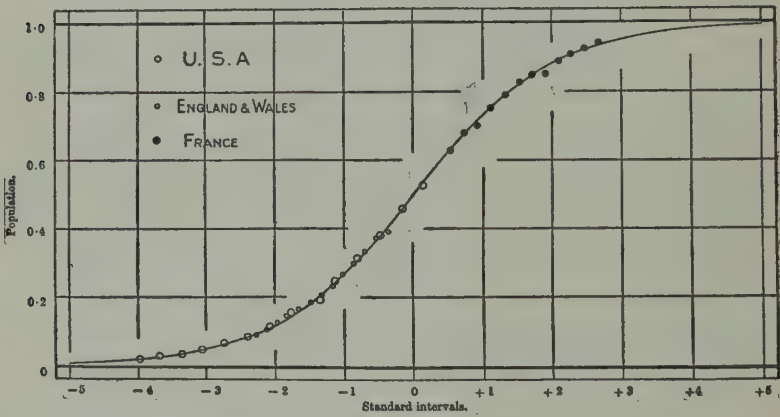

FIG. 8. The population of the United States (1790–1920), England and Wales (1801–1921), and France, including Alsace-Lorraine (1801–1911) fitted to the same logistic drawn to the standard time scale. (From Yule).

In the face of the considerable evidence now at hand, which could be still further multiplied, it is irresistably borne in upon one that all the complexities of human behavior, social organization, economic structure, and political activity, seem to alter much less than would have been expected the results of the operation of those biological forces which basically determine the course of the growth of populations of men, as well as those of yeast cells and, as will be seen in Chapter II, flies. The half-pint universe of the laboratory *Drosophila*, in its quiet incubator, is without doubt a simpler world than that in

which we carry on, but in both the great realities of birth and death are much the same. And it is these that count.

IV

In all the cases so far considered it is apparent that we have been dealing with growth in a single cycle or epoch. But obviously such a scheme does not encompass the whole history of population. Man has passed through a series of cultural epochs in the short period of his known history. Every advance from a lower to a higher civilization, using civilization as a descriptive term for man's attained power to derive from his physical environment things conducive to his comfort and pleasure, has increased the potentialities of population growth in a given area. In the hunting stage of civilization a very wide area was required to support a given human population. In the agricultural stage the same area could easily support many more people.

So then what probably happened in regard to population growth was that during each successive broad cultural epoch in the history of mankind the population within a given area grew according to our stretched-out S shaped curve. But when, owing to discoveries and consequent changes of habits, a new cultural stage was entered upon, a new cycle of population growth was also begun, starting from a base line of the already attained population at the end of the old epoch.

Unfortunately systematic census taking is such a relatively modern enterprise that it is impossible, except in a few cases, to get definite proof that such a process as that outlined occurs in population growth. In two cases, however, a rather sharp passage of a nation from the predominantly agricultural to the predominantly industrial forms of civilization has occurred within recent historical times. These are Germany and Japan.

We can take the space only to discuss briefly the growth of Germany's population.

Fifteen years before the Franco-Prussian War, Germany, which was still predominantly in the agricultural stage of civilization, was experiencing a slowing rate of population growth, such as is characteristic of the latter half of any single cycle of growth. During the next twenty years she made an enormous industrial development and, indeed, passed definitely into that stage of culture. Her population began to grow at the increasingly rapid time rate which is characteristic of the first half of any single cycle of growth. The facts regarding population are shown in Fig. 9. The data from which this diagram is plotted are given in Appendix Table 8.

The two smooth curves are single cycle growth curves identical in mathematical type with the curve which we have seen to describe so successfully the growth of the populations of Sweden, the United States, and France. Welded together these two single cycle curves fit with the nicest precision the complicated, wiggling line presented by Germany's observed population history (represented by the small circles).

The equations to the two single cycle curves are as follows:

For the period up to 1855, $$y = 10.109 + \frac{34\,036}{1 + 2.495\, e^{-0.0394x}}, \qquad \text{(ix)}$$

From 1855 on, $$y = 33.587 + \frac{82\,944}{1 + 297.546\, e^{-0.0472x}}, \qquad \text{(x)}$$

The moral of this case plainly is that even when human social evolution does manage to put a kink in the curve of population growth, it has not done it by altering any biological law. It merely shifts, by a greater or smaller amount, the absolute base from which the law operates. Then the process goes on as before.

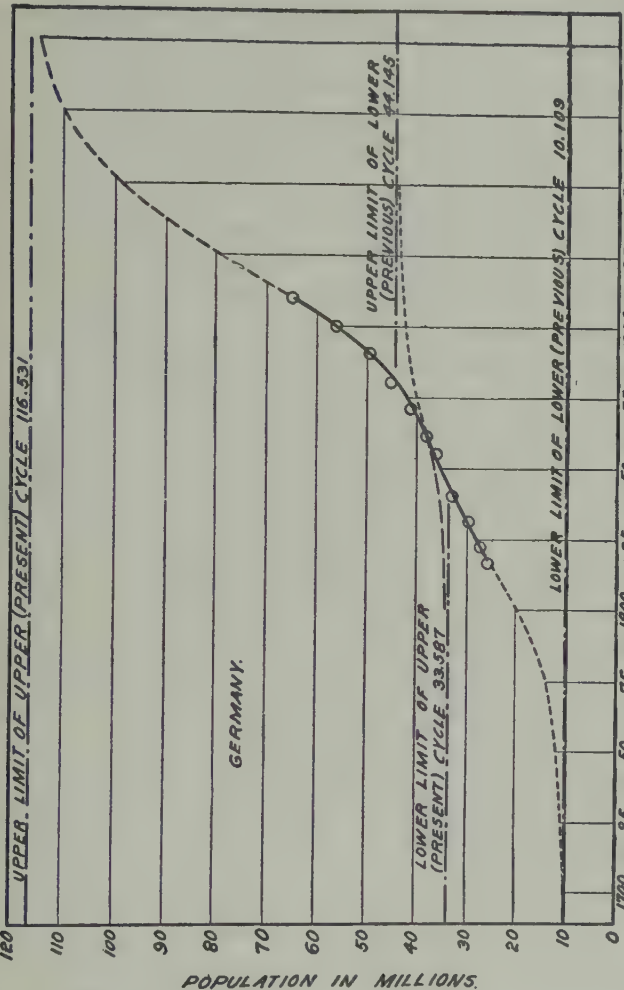

FIG. 9. The population growth of Germany, showing two cycles of growth which have overlapped during the period of census history.

Japan offers an illustration of the same sort as Germany. Unfortunately Japan's census data are only recent and do not furnish as much material as would be desirable for an adequate mathematical analysis.

V

In the matter of population growth there not only "ought to be a law" but six years of research has plainly shown that there is one. This is not the place for recondite statements in mathematical shorthand, but fortunately it is possible to state the law of population growth in plain language, without resort to mathematical symbols. It may be put in this way:

Growth occurs in cycles. Within one and the same cycle, and in a spatially limited area or universe, growth in the first half of the cycle starts slowly but the absolute increment per unit of time *increases* steadily until the mid-point of the cycle is reached. After that point the increment per unit of time becomes steadily *smaller* until the end of the cycle. In a spatially limited universe the amount of increase which occurs in any particular unit of time, at any point of the single cycle of growth, is proportional to two things, viz: (a) the absolute size already attained at the beginning of the unit interval under consideration, and (b) the amount still unused or unexpended in the given universe (or area) of actual and potential resources for the support of growth.

The latter element (b) wants a little further explaining. In the case of human population growth the unused and unexploited store of resources for subsistence will include such things as the amount of agricultural land still untilled, or not cultivated to the maximum of productivity. New discoveries of improved agricultural methods, or of chemical methods of making food synthetically, will at once increase the importance of this factor in the case. The result will be either to move up somewhat the upper limiting value of the population attainable in the current cycle of growth, or, if the potential addition is larger, to start the population off upon a new cycle of growth. Factor (b), in the case of human population may

also mean such things as the potential development of transportation, power resources, etc. In fact, it was the unexpected development of just such things as these, making possible the birth and growth of large scale industrialism, which upset Malthus's calculations as to the time when population saturation would make its effects uncomfortably felt. In the case of a simple experimental population like that of yeast cells the (b) element means practically the still unused amount of sugar and salts remaining in the given limited volume of solution in which the cells are growing. Its value can be quantitatively determined in this simple case, by chemical analysis of the solution at successive stages of the growth cycle. For obvious reasons it cannot be accurately measured in the case of human populations. In the case of the growth in size of a single individual organism, like the white rat earlier discussed, the meaning of this factor (b) is somewhat more difficult to define. It probably signifies the still remaining potentiality of the system of mutually inter-dependent cells and organs to expand in space without losing effective biological touch with each other. Just as in the case of human population it has been found possible, by appropriate procedures, to move to a higher level the upper limit to the growth in size of an individual organism within a single cycle. I refer to such matters as the influence of endocrine secretions upon growth. This, however, takes us into a large and important field of experimental biology, which cannot be discussed here.

Having got some insight into the underlying law according to which population growth occurs, and having found that this is of a sort capable of mathematical expression, we are able to approach the general problem of population along several pathways not previously open. We can, for example, upon a more adequate scientific basis than mere guess-work, predict future populations, or estimate past populations, outside the

range of known census counts. This has been done in the diagrams presented earlier. The theoretical curve which is believed to express the law of population growth has been extended, in each of the diagrams for human population, in the form of dotted lines, to the ends of the current cycle of growth. These dotted lines represent the probable future (and past) populations on the assumption, be it clearly understood, that no fundamental alteration in factor (b), as stated above in the definition of the law, occurs prior to the completion of the present cycle of growth. If such alteration does occur, then the predictions based upon the absence of such alterations during the past history of the present cycle, obviously become worthless. The whole case has to be reconsidered in the light of the changed conditions. But if no such alterations occur before the completion of the present cycle of growth, the maximum population, in this cycle, of the several countries discussed will presumably be, in round numbers, about as follows:

Sweden	7.9	millions
United States	197.3	"
France	42.6	"

Undue absolute weight is not to be given these predictions. It is extremely probable, I should think, that events like scientific discoveries, military conquest, etc., will alter factors (b) for nearly or quite every country in the world during the next hundred years say. The figures really express what the probable future populations would be if the conditions of the nineteenth century were to remain permanently unaltered. For the next ten or twenty years in the future the predictions given by the curves are undoubtedly highly accurate in most cases. But longer range predictions could be taken seriously only by someone who denies the fact of any and all evolution.

CHAPTER II

THE GROWTH OF EXPERIMENTAL POPULATIONS OF DROSOPHILA

I

In the preceding chapter it was shown that the growth of one of the simplest populations conceivable from a biological standpoint, one made up of individuals of the unicellular plant *Saccharomyces* commonly called yeast, followed with remarkable exactness the logistic curve. The simplicity of the case is in respect of several particulars. In the first place the individuals composing a population of yeast are each a single cell, microscopic in size, and but little differentiated. In the second place their environment is relatively simple and homogeneous. They live in a solution, which is not merely their environing and supporting medium, but also their food. Their life is in some part what ours would be if all the food necessary for our existence were derivable from the air which surrounds us, and if this food were taken from the air by our bodies by purely chemical means, without knowledge or effort on our part. In actual fact, of course the environment of any terrestrial animal is a much more complex and heterogeneous matter than is that of the yeast. There intervenes a soil-plant cycle between the animal which must have food and the inorganic world (see Lotka 157 for a detailed discussion of this and related cycles). Food has to be sought, and in the case of some animals, notably the highest, cultivated, if population is to make any considerable growth. The distance be-

tween an experimental population of yeast and any human population whatever, is biologically great.

Let us therefore take an intermediate step and examine experimentally the growth of population in the case of a multicellular animal, much higher than yeast in the biological scale, but still a great deal lower than man. For this purpose a suitable creature is the fruit-fly, or as it is sometimes called the vinegar fly, *Drosophila melanogaster*. It is the small fly, which looks to casual observation much like a diminutive replica of the common house fly, and is seen in swarms around decaying or fermenting fruit, or liquids like cider and vinegar made from fruit and left freely exposed to the air. Its suitability for laboratory experimentation arises from several considerations. In the first place it breeds rapidly and its life cycle is short. A female fly lays a good many eggs: under suitable conditions from 25 up to 40 or 50 a day for a period of at least 10 days. These eggs hatch in from 24 to 48 hours into little larvae or maggots, which squirm around in and feed upon the decaying vegetable material in which they are laid, for three or four days. They then seek a dry spot, settle down and transform into the next stage in which they have their being, the pupal. From each pupa emerges in about four or five days a fully formed adult fly or imago, which promptly mates and, if a female, starts laying eggs in from 12 to 24 hours. So then a whole generation, from adult (imaginal) parent to adult (imaginal) offspring occupies, on the average and under suitable conditions of food and temperature, only about 10 or 11 days.

A second advantage of *Drosophila* for experimentation lies in the relatively simple and easily standardized husbandry which suffices to meet its needs. The flies may be satisfactorily grown in ordinary half-pint milk bottles, stoppered with a loosely packed wad of cotton wool, like a bacterial culture

tube. The bottom of the bottle to the depth of three quarters of an inch is covered with a sort of gelatinized banana pudding of standardized composition.

The food base used in the experiments to be described was made as follows:

To each 100 c.c. of water 2 grams of agar-agar are added. The agar and water are boiled until the agar is thoroughly dissolved. To each 100 c.c. of this solution are added 100 grams of ripe peeled mashed bananas. The whole is then boiled five minutes, and poured into bottles which have been well heated in oven (or sterilized in an autoclav). In the bottles for population growth a layer $\frac{3}{4}$ inch deep was initially poured. When the food has partly cooled there is sprinkled on top the smallest possible amount of pulverized dry yeast (shaken from a can with one pin hole in cover).

On this banana-agar medium the eggs are laid. The larvae burrow about in and at the same time grow fat upon the nourishing jelly. On the surface of the banana jelly a luxuriant growth of yeast develops. This yeast serves as the principal food of the adult flies which emerge from the pupae.

Such a bottle is a dipteran microcosm, a spatially limited but well equipped universe. The banana jelly is the tillable soil, the agricultural land from which comes the plant food (yeast) which enables the animal population (the flies) to complete its cycle. The larvae are in some sense the tillers of the soil. They plough about in the jelly, ever more deeply and thoroughly seeding it with yeast cells.

Suppose now that we put into such a half-pint universe of fresh virgin soil, and all clean and new, a family of flies. Let us make the family consist of several individuals: Adam and Eve, a few young children (larvae) and a few older children (pupae). Then let us watch nature take her accustomed course. In due time more children will be born, since *mère*

and *père* are no slackers in the chiefest of biological duties and privileges. Some will die. Others will grow up and have offspring of their own. Ultimately the old folks will pass away, but not before there has accumulated around them a great crowd of their descendants of several generations. In short a *population* will have grown in this little universe.

The appearance of the experimental bottles at different stages in an experiment on population growth is shown in Fig. 10. Bottle A shows the condition at the start. The banana-agar jelly at the bottom has on its surface a luxuriant growth of yeast, ready to serve as food for the flies. Bottle B shows a later stage where the population has greatly increased, as may be seen from the numerous pupa cases on the side of the bottle. Finally bottle C shows a late stage where the food resources of the half-pint cosmos are nearing exhaustion.

For this qualitative picture of the course of events, we may substitute an exact quantitative one by the simple expedient of taking a census of the population at frequent intervals, say every second or third day. The manner in which the census is taken is important. It must be so managed that the individual flies can be accurately counted and at the same time not injured in any way, nor removed more than temporarily from their snug half-pint universe. The method worked out for doing this (87) is as follows. First we had a glass blower construct the device shown in Fig. 11, called a *counting tube*.

When it is desired to count the number of flies in a bottle the small aperture *a* is temporarily plugged with a bit of cotton wool, the plunger *P* is removed from the tube and all the flies in the particular half-pint universe are shaken into the counting tube by inverting the open bottle containing them over the funnel mouth of the counting tube. Then the plunger

A B C

FIG. 10. Half-pint milk bottles at different stages in a population experiment. For further explanation see text.

is inserted and gently moved forward to concentrate the flies in the lower end. Then the counting tube with enough cotton around it to close up the mouth of the bottle is inserted into the bottle into which it is desired to place the counted flies

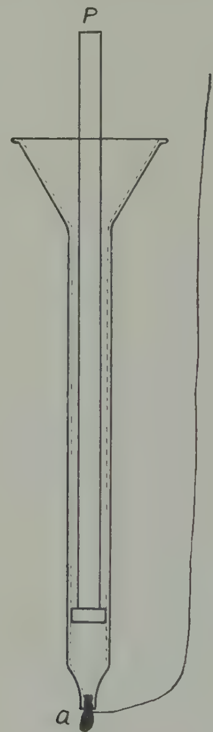

FIG. 11. Diagram showing construction of *Drosophila* counting tube. The aperture at *a* is just large enough to allow one fly to pass through at a time. The essential dimensions are as follows: length over all 25 cm., diameter of main tube 2 cm., diameter of funnel mouth 6 cm.

(in this case the same bottle from which they originally came) and the plug removed from the aperture *a* by pulling the thread attached to it. Then as the flies come out of the tube,

one by one, through the aperture *a*, they are counted as they pass this point, with the aid of a tally register, such as is used by doorkeepers at theaters. The plunger is gently moved forward as necessary to keep up an even flow of flies through the mouth of the tube. The whole process takes but a short time, is exact, and can be repeated as often as one likes.

II

There are several ways in which an experiment on the growth of a *Drosophila* population can be carried out. Some of these ways differ in principle in a manner that is of importance in determining the kind of result obtained. Before discussing the actual experiments it will be well to examine with some care the theoretical considerations involved.

To take the simplest case first it is apparent that if we set up an experiment in the manner described above, and thereafter literally do nothing further except to let nature take its course and count the flies at intervals, something like the following will happen. The adult flies will eat the yeast, and the larvae will eat the banana-agar substratum. The animals (flies) will outrun the means of subsistence (yeast and banana-agar), since there is at the start no limitation on the number of animals, and a very distinct limitation on the means of subsistence, imposed by the size of the universe. If no food is added from the outside a point is fairly soon reached when the adult flies will literally have eaten up all the yeast in their universe. There remains then but one thing left for them to do, which is to starve to death. This they rather promptly do. Presently some new adults hatch out from the larvae and pupae produced from eggs laid while there was yet some food left for the adults. But these new adults starve to death because the universe into which they were born has none of

their kind of food. So presently the bottle becomes an empty, burned-out universe, incapable any more of supporting any population at all.

If during this process census counts are made of the population what is found is that the population grows for rather more than one-half a complete cycle of the logistic curve; and then quite suddenly after the critical point of balance between population and food supply is passed begins to decline, and finally disappears completely.

This experimental picture corresponds in its latter part to what would happen to a human population, such as that of the United States say, if it were suddenly confronted with the situation that not a single scrap of human food could thereafter be either produced or imported. When the stock on hand was all eaten up people would promptly begin to starve to death. Very presently the human population would simply not exist at all.

But obviously such an experiment does not parallel at all the actual situation regarding human populations. The world's farmers are always producing more food. Perhaps, as Malthus and others down to East have pointed out, the rate of production of food is not as rapid as the rate at which human beings have young. But at no time has the production of food entirely and permanently ceased. If it had, none of us would be here. So then, while we have carried out in the laboratory, and will later publish the results of, experiments planned like the above to study the growth and decay of fly populations in the absence of added food, they have no pertinent bearing upon the present discussion, and will therefore not be considered here.

The type of experiment which is of interest in the present connection is one in which the annual addition to the world's human food supply, which the harvest brings in, will be

imitated as closely as possible in the half-pint bottle. In practice it is extremely difficult to imitate successfully this condition in the experimental bottles. If new food (banana-agar) is poured on the top of the old and allowed to harden some undesired alterations are made in the situation. The larvae are buried and have to work their way up through the added food. Also the total thickness of the food at the bottom of the bottle is increased by these additions and encroaches more and more upon the air space left for the flies in the rest of the bottle. Finally, the old, worn-out, and ultimately decaying food at the bottom is not removed by this additive procedure, and eventually it stops by its presence the continuation of the experiment. However, by adding new food skillfully and in small amounts it is possible to carry an experiment through to completion of the population growth cycle by this method. In the experiments which follow this was in fact the method used.

Another practical difficulty in these experiments arises out of the fact that during the first 10–12 days of an experiment no increase in the adult, countable population occurs, and then at the end of that period there is a sudden jump upwards in the number of imagoes. This happens, of course, because the duration of a generation from egg to egg is 10–12 days. If one starts with two flies, a male and female, their progeny which will make the first increase in the population do not emerge as adults (and therefore countable) until about 11 days after the start. In the intervening period the population of imagoes stays constant at two. Of course the way to meet this difficulty is to introduce at the beginning not merely adults, but also some larvae and pupae of different ages so as to get overlapping of generations as soon as possible. It is difficult in practice to get in these young in just the right proportions to make the curve go along smoothly at the very

start. On this account the experimental results shown in the next section are generally somewhat irregular at the start of the curve.

III

In this section will be presented the results of some typical experiments which have been made in my laboratory on the growth of *Drosophila* populations. The experiments have been repeated and always with similar results, provided the food conditions are properly managed.

The first experiment, the results of which are shown graphically in Fig. 12, and numerically in Appendix Table 9, is the averaged result of two half-pint bottles. Each bottle was started on the same day with two adult wild type flies (one male and one female). A small amount of food was added when the census counts were made beginning April 26. In this, and all the other experiments the bottles were kept in electric incubators at a constant temperature of 25° centigrade throughout the course of the experiment.

The observations (average of bottles 1 and 2) were fitted with a logistic curve, of which the equation is

$$y = \frac{212}{1 + e^{4.69 - 0.27x}}, \tag{xi}$$

in which y denotes population and x time in days.

It is obvious both from Fig. 12 and Appendix Table 9, that the observed growth of this fly population is, on the whole, accurately described by equation (xi). The only serious discrepancy is in respect of the early observations (April 21 and 23). Here the curve lies distinctly above the observations. This, however, arises from the fact that the bottles were started with only one pair of adult flies, and on the two dates mentioned we are dealing solely, in the observation, with the children of the two original parents. None of the grand-

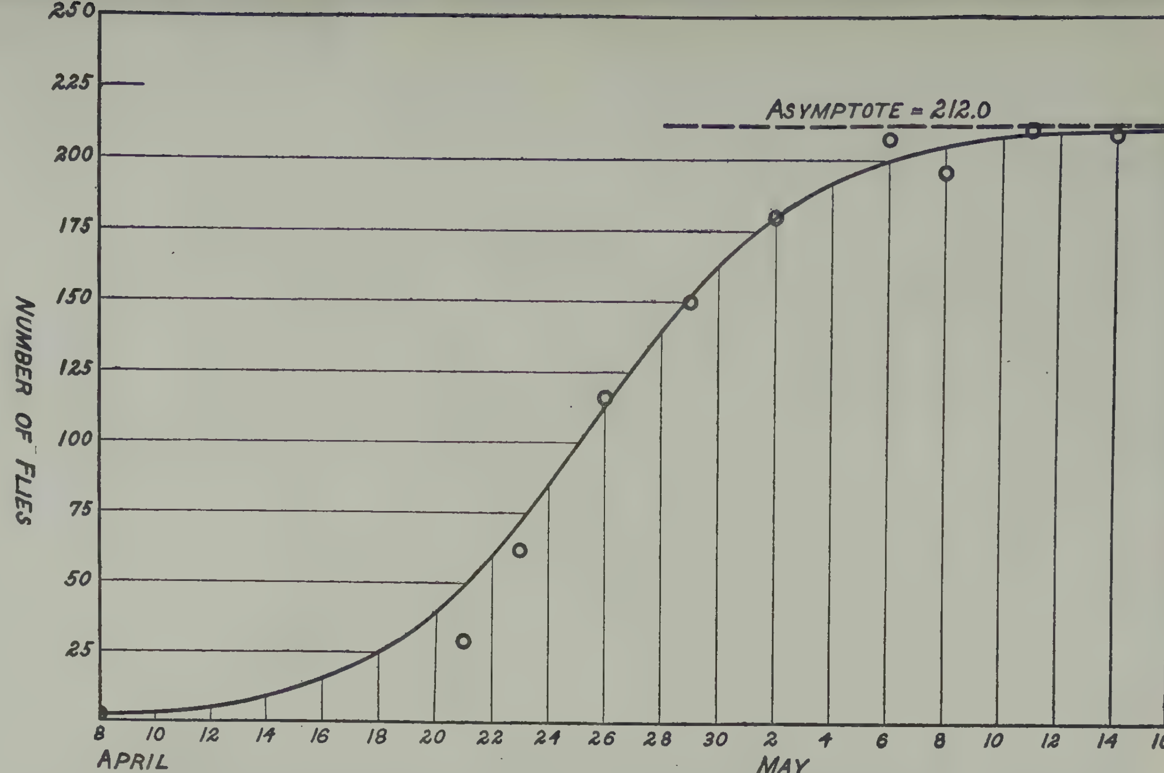

FIG. 12. Growth of wild type *Drosophila* population in half-pint bottles. The circles give the observed census counts and the smooth curve is the graph of equation (xi).

children have yet emerged. We are in short seeing at these early dates only family, and not population growth; and since we count only adults (imagoes) in the censuses taken, we have only a part of the family growth. From April 26 on overlapping of generations has begun and we get true population growth.

Let us next examine the effect of starting with an initial "seed" or pioneer population somewhat larger in size and of a varied age composition, and also of establishing them in a larger universe. Experiment 7 was carried out in a pint milk bottle instead of a half-pint. The initial pioneer population with which the experiment started was made up as follows:

2 males, 1 female, each 1 day old
3 males, 3 females, each 12 days old
4 males, 4 females, each 30 days old
2 males, 2 females, each 55 days old
1 female, 95 days old.

This makes a total of 22 adult flies (imagoes). In addition there were placed in the bottle at the start 12 pupae, and a small number each of eggs and of larvae. The number of the latter stages was not exactly determined but was known to be small. All the population was of the normal wild type *Drosophila.*

The results are shown graphically in Fig. 13, and numerically in Appendix Table 10.

The smooth curve in Fig. 13 is the graph of equation (xii) which also furnishes the calculated values in the last column of Table 10.

$$y = \frac{1035}{1 + e^{4.27 - 0.17x}}, \qquad \text{(xii)}$$

It is evident again that the logistic curve describes the growth of this experimental population in a satisfactory man-

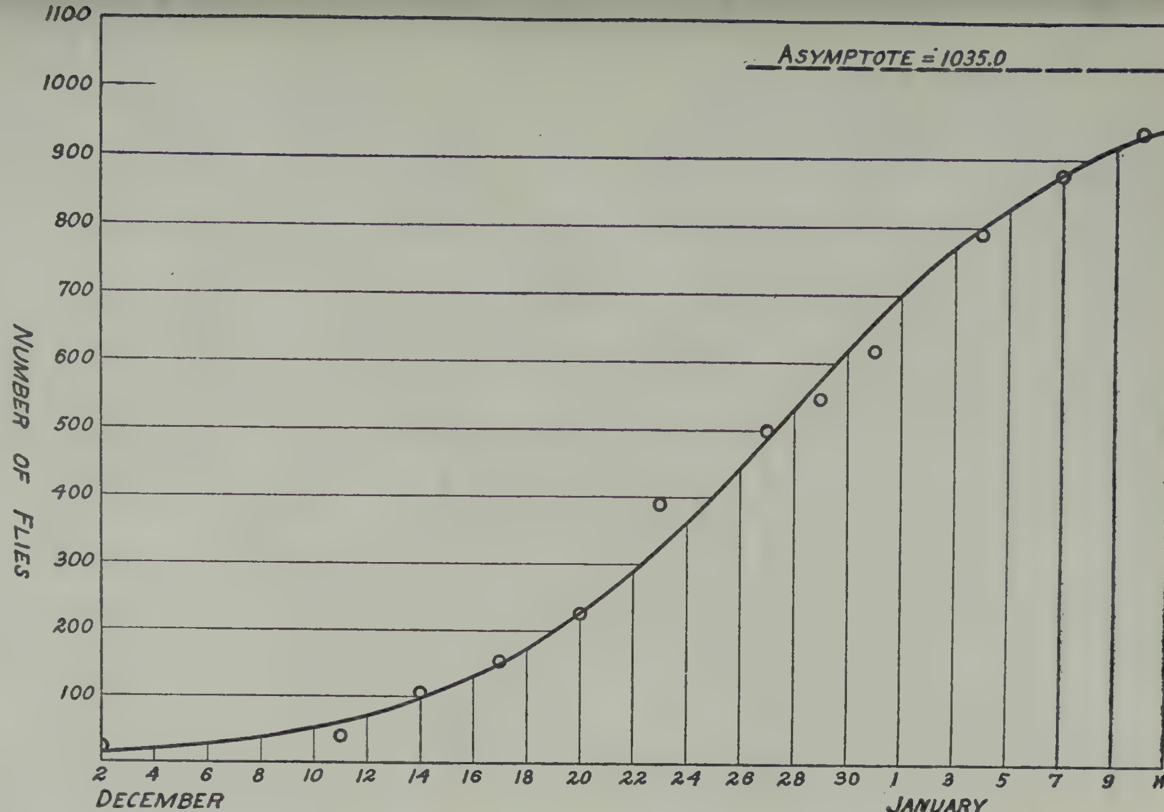

FIG. 13. Growth of wild type *Drosophila* population in a pint bottle. The circles are the observed census counts.

ner. Furthermore it is apparent that the stocking of the bottle with a pioneer population in which various ages were represented had the anticipated result of smoothing considerably the census counts in the early portion of the population growth. Unfortunately the observations did not reach quite to the upper asymptote predicted by the theoretical curve. The reason for this is a purely practical one. After January 10 the food became unmanageable. The agar jelly softens after a time and becomes loosened from the walls of the bottle. The result is that the whole mass of food slides about when the flies are transferred to the counting tube, many flies are killed mechanically, and in general it becomes impossible to go on. The observations in this case, however, extend over so large a portion of the whole range of the theoretical curve as to leave no doubt that this curve represents the law according to which the fly population is growing.

Let us consider a third and final example of the growth of an experimental *Drosophila* population. This time the material consisted of another type of *Drosophila,* namely a mutant form *Quintuple* which differs from the normal wild type fly with which we have dealt in the previous experiments in that it carries the mutant form of five unit characters, instead of the normal form found in the wild flies. Of these five mutations the only one of importance in the present connection is that involving the wings, and called *vestigial.* This mutation is described by Morgan and Bridges (88). In flies carrying this mutant gene the wings are reduced to mere vestiges of their normal condition, as shown in Fig. 14. In consequence of this reduction in the wings these flies are incapable of flight. They move about by walking and jumping in the manner of fleas. Associated with the presence of this mutant gene are also a reduced fecundity and fertility, and a much shortened duration of life, as compared with the wild type fly (cf.

Pearl, Parker and Gonzalez (89), Pearl and Parker (90), and Gonzalez, (91)).

In this experiment a pint milk bottle was started on October 6 with an initial population of quintuple flies made up as follows:

FIG. 14. A. Normal wing of wild type *Drosophila melanogaster*. B. Vestigial wing. Both magnified equally to × 42.5. (Drawn by Miss Maria Wishart).

2 males each 15 days old

1 male and 3 females each 2 days old

12 pupae, and a small number of eggs and larvae.

The results are shown graphically in Fig. 15 and numerically in Appendix Table 11. The equation of the smooth curve is

$$y = \frac{346.14}{1 + e^{5.34 - 0.22x}}, \qquad \text{(xiii)}$$

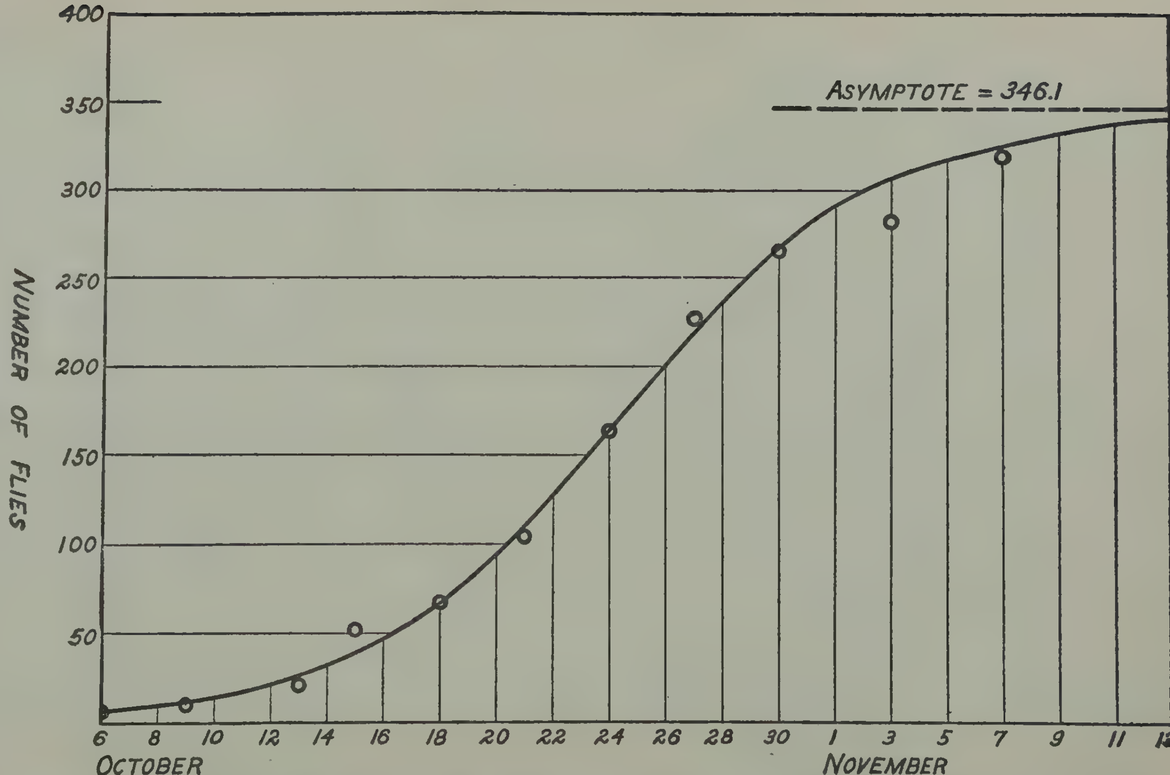

FIG. 15. Growth of population of quintuple mutant stock of *Drosophila* in a pint bottle. The circles give the observations and the smooth curve is the graph of equation (xiii).

Except for the last two observations at the upper end of the curve the agreement again is satisfactory between theory and observation. The trouble here, as before, was that the food was getting out of control, and after November 7, it became impossible to continue the experiment.

Taking all the evidence together, which might be multiplied from the laboratory records, it may fairly be taken to be demonstrated, I think, that the fly *Drosophila* in its population growth under controlled experimental conditions follows the logistic curve.

IV

There are certain points in regard to the evidence presented in the preceding section which want further discussion. In the first place it is to be noted that doubling the size of an experimental universe does not exactly double the size of the asymptotic or maximum population which will develop in it. Thus, for wild type flies in half-pint bottles the upper limiting population from equation (xi) is 212, while for the same kind of flies, and with all other environmental conditions the same except that the size of the universe is doubled by using a pint bottle, the upper limiting population from equation (xii) is 1035. In other words the maximum population is nearly *five* times as large, instead of twice, in the pint bottle as it is in the half-pint. The actual amount of free air space available, after allowing for the space occupied by the food and the cotton stoppers is on the average for the half-pint bottles 167 c.c. and for the pint bottles 375 c.c. Thus while the latter fly universe has a little more than twice as much free air space as the former, it has nothing approaching five times as much.

If the surface area of the food, namely the area on which the adult flies can find yeast to eat, be considered, the facts are that in the half-pint bottles 24.2 square cm. of food area are

available, and 39.6 square cm. in the pint bottles. In this respect the case is obviously worse. The ratio of the larger to the smaller universe is not even so great as two.

Let us look at the matter in still another way. The density of the fly population at any time may be defined as

$$d = \frac{N}{v} \tag{xiv}$$

where d denotes density, v the volume of the effective free space in the universe measured in cubic centimeters, and N the number of flies in the universe at the time. Equation (xiv) will then state the average number of flies in each cubic centimeter of free space in the universe.

Then for the asymptotic populations given by equations (xi) and (xii) we have

$$\left.\begin{array}{ll} \text{For half-pint bottle, } & d = \dfrac{212}{167} = 1.27 \text{ flies per c.c.} \\[2ex] \text{For pint bottle, } & d = \dfrac{1035}{375} = 2.76 \text{ flies per c.c.} \end{array}\right\} \tag{xv}$$

These results at once put a new complexion on the matter, as will be apparent if we compare certain ratios as follows:

$$\left.\begin{array}{l} \dfrac{\text{Density of asymptotic population in pint bottle}}{\text{Density of asymptotic population in half-pint bottle}} = \dfrac{2.76}{1.27} = 2.2 \\[2ex] \dfrac{\text{Total free space in pint bottle}}{\text{Total free space in half-pint bottle}} = \dfrac{375}{167} = 2.2 \end{array}\right\} \tag{xvi}$$

Or, as the event turns out, we may state the result expressed by (xvi) in this way: that so far as these experiments indicate, *the density of the asymptotic population varies directly as the volume of the universe.* But this obviously means that in these experiments the *absolute size of the asymptotic population varies as the square of the volume of the universe in which it grows.*

Thus in the present case if we call the available free volume of the half-pint universe 1, that of the pint universe is 2.2455. We then have for the expected number of flies in the pint universe at the completion of the cycle of growth

$$212 \times (2.2455)^2 = 1069 \text{ flies}$$

The corresponding asymptotic number from equation (xii) is 1035. The approximation is certainly close, considering all the experimental difficulties involved.

It must be remembered that the precise mathematical relationship between the size of the maximum or asymptotic population and the volume of the universe stated above is deduced from only two series of experiments and may not hold in just this form over a wider range of volumes. It is also important to remember that in these experiments essentially all other conditions were held constant except the volume of the container. In particular the flies were of the same sort genetically, or racially, throughout. Furthermore, food, temperature, and other environmental factors except volume of universe were the same in both series. None of these conditions are realized when two human populations are compared, as for example the population of France and that of the United States. The people who make up these populations are racially different and have genetically different fertility rates. Furthermore virtually all the environmental conditions are different in the two countries. For such reasons as these it is not to be expected that the simple numerical relationship between size of asymptotic population and size of universe which holds in the experimental *Drosophila* populations here dealt with will be valid for human populations in countries of different sizes.

The work on experimental populations of *Drosophila* is being continued and it is expected that later reports will deal

in detail with various quantitative aspects of the matter which cannot be gone into here.

The second point which I wish to make regarding these experimental *Drosophila* populations is that they demonstrate the importance of the fact alluded to above that racial differences have much to do with determining the rate of growth of populations and the final asymptotes approached. Thus if equation (xiii) be compared with (xii) it is seen that the asymptotic or maximum population is 346.14 in the former case and 1035 in the latter. Yet the experiments were in every respect identical except that in the former case the flies were quintuple mutants and in the latter of the normal wild type.

The asymptotic density indicated from equation (xiii) is

$$d = \frac{346.14}{375} = 0.92 \text{ fly per c.c.} \tag{xvii}$$

This is exactly one-third only of the asymptotic density of 2.76 flies per c.c. found for wild type flies under the same experimental conditions in equation (xv). This result simply reflects the known lower fecundity and fertility and the higher mortality rate of Quintuple as compared with wild type flies.

It seems to me highly probable that this factor of differences between different countries in respect of the genetic constitution of their inhabitants is an extremely important one in bringing about the observed differences in density of human populations at corresponding points in their cycles of growth.

At this point we may leave for the present the consideration of experimental populations and turn to human material. Later in the book we shall come back again to *Drosophila* for further pertinent data.

CHAPTER III

THE INDIGENOUS NATIVE POPULATION OF ALGERIA

I

It is generally difficult, to a degree nearing impossibility, to approach some of the most significant problems of human biology analytically. In countries where there are sharp and real discontinuities in the racial composition of the population (with associated wide differences in mores) the statistical records are usually fragmentary or unreliable or both. On the other hand, in countries where the official statistics are respectable there is usually found such a degree of homogeneity in the social structure and mores at least, or the differentiations in these respects and in race are in such a state of entanglement or of flux, as to make anything approaching conclusive analysis impossible. In short it appears that in most cases where Nature has staged a reasonably simple experiment in human biology man has neglected to take adequate records about it, and commonly where detailed and tolerably accurate records are kept the general *mise en scène* is far from that of a simple experiment.

In this situation any case which offers both adequate records and clean-cut racial and social discontinuities on a scale of respectable statistical magnitude is worthy of careful consideration. Something approaching such a case seems to be presented by Algeria. My attention was first directed to this fact by a recent memoir of Bunle (1). He has given an extremely thorough and comprehensive résumé of the recent

demographic statistics of Algeria, Tunisia, and French Morocco. Certain of the data had such an obviously pertinent bearing upon the problem with which this book has to do that I was led to look further into the history, ethnology and statistics of Algeria, with the results set forth in this and the following chapters.

II

As everybody knows, Algeria has been since about 1830 under the dominion of the French. This control became overt about the middle of the nineteenth century. Warren (34, p. 159) says on this point: "Constantine fell in 1848. Then France who up till then had waived aside the questions of other powers as to her intentions, openly declared Algeria French territory, and with 'hands off!' gesture to the world, continued her conquest and colonization of what is now a most valuable and prosperous dependency." Algeria is divided naturally, and since 1906 administratively, into two parts; the *Territoires du Nord*, with an area of 207,915 square kilometers and a total population in 1921 of 5,258,000, giving a density of 25 persons per square kilometer, and the *Territoires du Sud*, with an area of 367,596 square kilometers and a total population in 1921 of 548,000, with a density of 1.5 persons per square kilometer. The latter portion is mainly desert.

Bunle (1) gives a detailed account of the methods of census enumeration employed in *recent* times in Algeria. They are essentially the same as those used in Paris and France, with such minor modifications as the environmental and social peculiarities of the country entail. It appears from his account as well as from other evidence (*cf.* for example 2–5) that, except in the *Territoires du Sud*, the degree of accuracy of the census returns during the last 40 years or so is of approximately the same order as that in France itself. Even in the

TABLE I

POPULATION OF ALGERIA. 1901–1921

Census year	Europeans								Indigenous natives	Total civilian popula-tion	Total population including persons in military service and others not counted in pre-ceding columns.
	French by birth	Naturalized French			Foreign						
		Israel-ites	Other foreign	Total	Spaniards	Italians	Other nation-alities	Total			
1901	292,464	57,132	71,793	128,925	155,265	38,791	25,531	219,587	4,098,355	4,723,000	4,739,331
1906	278,976	64,645	170,444	235,089	117,475	33,153	15,570	166,198	4,477,788	5,158,051	5,231,850
1911	304,592	70,271	188,068	258,339	135,150	36,795	17,167	189,112	4,740,526	5,492,569	5,563,828
1921	405,208	73,967	123,484	197,451	144,328	31,927	12,519	188,774	4,924,938	5,716,371	5,806,090
Growth per cent from 1901–21	+ 38.5	+ 29.5	+ 72.0	+ 53.2	− 7.0	− 17.7	− 51.0	− 14.0	+ 20.2	+ 21.0	+ 22.5

desert country of the Sud a carefully worked out administrative machinery is in operation, and probably secures at the present time results nearly or quite as accurate as those in the more remote rural parts of our own southern and western states.

The constitution and growth of the population since 1901 are shown in Table I (Bunle, *loc. cit.* p. 287) and (48, p. 16).

This table is presented in part to furnish a general demographic background for the discussion to follow. It also, however, introduces the first point of biological interest. This is in regard to the *growth* of the indigenous native population. We have here a case of natural population growth only very slightly affected by migration. This is demonstrated by the figures of Table II, condensed from one given by Bunle (p. 355). In this table are given the *net* migration figures for the total population, including both persons of European origin and indigenous natives. When the figure is plus it means that in that year immigration exceeded emigration; when it is minus the balance was on the side of emigration. The data include arrivals and departures both by sea and by land.

TABLE II

MIGRATORY MOVEMENTS BETWEEN ALGERIA AND THE EXTERIOR.

Year	Net migrants	Year	Net migrants
1901	− 5,600	1908	+ 6,800
1902	− 13,500	1909	+ 11,000
1903	+ 9,900	1910	+ 600
1904	− 1,400	1911	− 3,100
1905	+ 5,100	1912	+ 15,000
1906	+ 8,900	1913	+ 400
1907	− 4,700	1914	− 53,900

It is obvious that in a total population of between five and six millions such small net migratory movement as that indi-

cated in Table II is negligible. Furthermore it is plainly of about the magnitude which would be expected if it were composed chiefly of French. This appears in fact to have been the case until the war and post-war period. The growth of the native population may be regarded as not sensibly influenced by migration. The greatly increased figure for 1914 is due to mobilization of the French forces in France.

The native population of Algeria is ethnically chiefly Arab and Berber. In 1911, 770 per thousand of the native French subjects were Arabs and Arabic speaking peoples (Arabophones in Bunle's convenient terminology), and 230 per thousand were Berbers, Berberophones, Kabyles, Mozabites and Tuaregs. These different racial elements in the native population are widely and deeply different in many respects of psychology, social organization and mores, as well as in physical structure and ethnic origin. A popular and at the same time accurate brief account of the customs of these people is given by Douglas (6). Fribourg (7) says (p. 41): "Les différences sont profondes entre l'Arabe et le Berbère. L'Arabe, en principle, est nomade." The Berber, on the contrary, and especially the Kabyle Berber, has a great attachment to the soil. This is shown statistically, in a not unhumorous manner, by the extent to which the Kabyles have bought back their land from French colonists, to whom it had either been given outright or sold at a low price by the government, following its expropriation from the original native inhabitants, as a part of the business of conquest. An interesting official table, showing the real estate transactions both ways between Europeans and natives for each year from 1880 to 1921 inclusive, is given on page 32 of (5). Fribourg (7, p. 43) says of the Kabyles on this point: "In vain did the Administration confiscate their land following the revolt of 1871. In vain did it establish colonists on the confiscated

property. . . . Little by little and at any price the Kabyle has bought back from the European proprietors the land lost for a moment, just as he has bought back in the towns, as at Tizi-Ouzon for example, one by one, all the houses."

General references regarding the ethnic characteristics, customs, etc., of the native population of Algeria are (2), (4), (5), (8) to (26) inclusive, (50), (92) to (101) inclusive. Jones and Dow (146) give an excellent brief account of present conditions in Algeria.

The data of Table I show that both the time rate of growth (increment per unit of time) and the percentage increase (percentage, which increment in a given time interval is of the already attained population at the beginning of the interval) of the native population of Algeria have been becoming progressively smaller in the recent past. In fact this population presents precisely the picture of an approach to the end of an epoch or cycle of growth (27). This fact is of so much interest as to warrant more detailed study. The only other human population known to be in relatively the same position in the cycle, and at the same time having reliable census data available, is the population of France. The French are perhaps the most highly civilized people in the world. The indigenous natives of Algeria are far from that. That both of these populations should be growing during the same recent and current time in about the same way is intriguing.

Fortunately there are available more data on which to study the growth of this indigenous native population than are given in Table I. In Appendix Table 12 is presented the complete census history of this moiety of the Algerian population (28, 48, p. 16).

At this point a brief résumé of certain important occurrences in the history of Algeria is necesary. On this subject the sources of information chiefly consulted are, for the early

history, Boutroue (102), d'Estry (29), Labiche (4), Fisquet (103), Napoleon III (30), Yver (31), Morell (95), Cats (32), Thomas-Stanford (33), Lady Warren (34), Vaillant (35), Boudin (36), Lavion (23), and especially for the detailed military history of the French conquest Laurie (51), Galibert (52), and Piquet (104); for the more recent, and political history (8), (37), Devereux (16), Wickersham (38), Philebert (39), Cros (40), Bach-Hamba (41 and 42), Ducos (43), Piquet (3) and (100), and Estoublon's and Lefébure's "Code" (44), which besides the texts of the various statutes themselves, gives in the foot notes a mass of valuable historical material.

For a long time prior to a few years before 1830 what is now Algeria had been at first actually, and later nominally under Turkish dominion. But for more than a century before this time the native inhabitants of this region pursued a course of self-determination in both internal and external affairs which was equally disconcerting to their nominal rulers the Turks, because of their refusal to submit to any but the most trifling overlordships, and to the rest of Europe because of the successful and persistent piracy they practiced on Mediterranean shipping. Various and sundry efforts were sporadically made by different European nations to persuade the rascals to be good, but all such attempts proved only ephemerally effectual. But in 1827 the Dey of Algiers slapped the French Consul's face,[1] and in 1829 the riotous populace fired on a French ship in the harbor of Algiers flying a flag of truce. These two events determined the French to take up the white man's burden in Algeria in good earnest. It required nearly fifty years to get the load firmly settled on their shoulders, a principal obstacle being one Abd-el-Kadir, obviously and admit-

[1] There is much conflicting evidence in the literature as to how hard he slapped it.

tedly a man of very considerable parts. This whole period was one of intermittent and guerilla warfare, with a steady increase of the power of the French over the situation, purchased at a price in both French and native blood.

Something of how dreadful was the price of empire paid by the French in these earlier years is shown by the figures of Table III, which relate to the army in Algeria. The data are from Boudin (36) p. 23.

TABLE III

DATA ON THE FRENCH MILITARY FORCES IN ALGERIA. 1831–1851

Year	Effective	Admitted to hospitals in Algeria	Died in hospitals of Algeria	Killed in battle
1831	71,190	13,524	1,005	55
1832	21,511	32,085	1,998	48
1833	26,681	27,934	2,512	64
1834	29,858	31,410	1,991	24
1835	29,485	34,094	2,335	310
1836	29,897	33,836	2,139	606
1837	40,147	51,136	4,502	121
1838	48,167	39,097	2,413	150
1839	50,367	53,194	3,600	163
1840	61,264	86,404	9,567	227
1841	72,000	88,383	7,802	349
1842	70,853	90,524	5,588	225
1843	75,034	77,306	4,809	84
1844	82,037	84,872	4,664	167
1845	95,000	89,849	4,664	601
1846	99,700	121,138	6,862	116
1847	87,704	108,290	4,437	77
1848	75,017	106,112	4,406	13
1849	70,774	105,469	9,745	...
1850	71,496	79,543	4,098	...
1851	65,598	76,118	3,193	...

The natives had no pleasant time in the same period, according to a variety of testimony (*cf.* for example Yver (31)

passim for numerical data on native casualties). Boudin (36) quotes Bodichon (Rev. d'Orient, no. de juillet 1841, p. 40) [2] to the following effect: " Sans violer les lois de la morale nous pourrons combattre nos ennemis africains par la poudre et le fer joints à la famine, les divisions intestines, la guerre, par l'eau-de-vie, la corruption et la disorganization." That this program of conquest, of such a *nette* 100 per cent character, was productive of results is indicated by the following statistical fragment, again furnished by Boudin (36). He states that amongst the Mussulman population of the towns in Algeria then under French control the following facts presented themselves.

1850		1851	
Births	Deaths	Births	Deaths
1128	4192	2439	5738

Doubtless the registration was not absolutely perfect, but Boudin was a careful vital statistician and much nearer the events themselves than we are, and thought the figures substantially accurate. The larger figures of 1851 mean in part merely added towns in that year. Vital indices (*cf.* 27 Chapter VIII), or birth-death ratios, of the order of 27 per cent or even 43 per cent are not characteristic of a happy and contented people in a healthy and peaceful environment. In this case they are not to be explained by differences in effectiveness of registration of births and deaths. They are on the contrary a grim commentary on the business of conquest, however one looks at them. Let it be hoped, however, that no one will draw an unwarranted conclusion respecting national ethics

[2] Original not seen by me. R. P.

or morals from what has been said. To avert such an intellectual *faux pas* I need only to direct the reader's attention to other times and other places. Consider a time only 13 or 14 years removed from these sad years 1850 and 1851 in Algeria, but *later,* and as *locale* nearly any of the cities of the southern part of the United States. Or again consider the city of Lille some 67 or 68 years *later* than the Algerian period under discussion. The fine points of General Bodichon's formula have been well appreciated by more peoples than the French. This consideration does not make the figures cited less grim, but ought, certainly, to make all of us more charitable.

By 1850 the essential work of conquest in Algeria had been accomplished. A wholesome respect for French authority had become quite widely established in the land, by a process akin to natural selection. There theoretically remained only mopping up and consolidation of the position to be accomplished. This, however, proved more troublesome than had been anticipated, and, taking one with another, a good many more natives had to be eliminated before the survivors were reasonably unanimous in their belief that the old days had gone forever. That even so late as 1871 one could take a very gloomy view of the situation is indicated by the following statement made by General Ducrot (45) at about that time:

"In Algeria the struggle between the conquerors and the natives is bound to be perpetual. No system which aims at fusion and assimilation of the natives has any chance of success.

"Force alone can subdue the Arab nation, — and, at that, can one suppose that the French under conditions no more favorable, will succeed in an enterprise in which so many others, — Carthaginians, Romans, Spaniards — have failed?

"There is no chance, then, of obtaining rapid and complete

development of colonization by Europeans until complete submission of the Arabs and Kabyles, — in other words, peace through solitude — has been obtained."

Regarding the psychology behind the insurrection of 1870–1871 a careful and temperate observer on the spot, Colonel Philebert (39) has the following to say (*loc. cit.* p. 7):

"In the native population, perhaps more than anywhere else, seethe passions akin to those which were exploited at the end of the Paris commune. The news quickly spread in this valley that authority was disorganized, that what was supposed to be at the bottom had risen to the top, and that the moment was propitious for those whose sole tribute to law is fear and whose sole property consists of strong arms and keen desires."

These extremely pessimistic views were vigorously combated by Ducos (43) at the time, and subsequent events in the peaceful development of Algeria showed that Ducrot was wrong in his prophecy, even though right in his summing up of past conditions. By 1880 the country was definitely in a peaceful state, the natives had accepted the new social order, and on March 23, 1882 a law was passed giving a definite civil status of sorts to the indigenous native population.

The bearing of the facts set forth in the above summary sketch upon the present purpose of studying the growth of the indigenous native population is as follows: The French, with characteristic systematic thoroughness began taking quinquennial censuses in 1856. But so far as concerned the native population it is clear that prior to the census of 1886 — the next following the establishment of civil status — the figures could at best be only estimates, and were in the nature of things likely to be underestimates. From 1882 on, as we have seen earlier in this chapter, there is every reason to suppose that the census enumerations of natives have been about as

accurate as counts of widely distributed primitive rural populations in other parts of the world. The precise manner in which these earlier censuses were taken is indicated by the following account (37, p. 13):

" Le dénombrement de la population a été opéré à la fin de 1876:

Nominativement, pour la population fixe des villes et des centres colonisés:

Numériquement, pour l'armée et la population " en bloc "; (on désigne sous le nom de *population en bloc,* le personnel des Établissements où sont réunis, temporairement, un certain nombre d'individus n'ayant pas dans la localité leur résidence municipale: prisons, hospices, lycées, collèges communaux, écoles spéciales, pensionnats, séminaires, communautés religieuses, etc., etc.):

Sommairement: c'est-à-dire par tentes et par douars, pour les tribus indigènes comprises en territoires de commandement. Le nombre total des habitants ainsi recensés s'élève à 2,867,626, savoir

" Armée	51,051
Français et naturalisés	189,680
Étrangers	155,069
Musulmans indigènes	2,462,936
Population en bloc	8,890
Total égal	2,867,626 "

III

In view of the much more certain character of the figures for the native population after 1882, the first trial approach to the analysis of the growth of this population was to endeavor to fit a logistic population growth curve to the data from 1886 to 1921 inclusive. A four constant curve of this type was fitted by the method of least squares to the seven

counts of the indigenous native population as given in Appendix Table 13. The equation found was

$$y = 3.108 + \frac{1.892}{1 + e^{2.079 - .7598x}}, \tag{xviii}$$

with origin at 1886, y denoting population in millions, and one unit on the time or x axis equalling five years. The upper limit of growth as indicated by the curve is at a population of 5,000,000 and the lower asymptote or starting point of the present cycle of growth at 3,108,000. The point of inflection of the curve was at approximately the middle of August, 1899. The calculated values from this curve are given in column B of Appendix Table 13. The form of the curve and its relation to the observations are shown graphically in Fig. 16.

This diagram, and the data on which it is based, present a number of points of interest. In the first place it is to be noted that the logistic curve describes the growth of the native population of Algeria since 1886 with considerable accuracy. With the exception of the year 1881, which was not included in the calculation of this curve (xviii) the percentage deviations between theory and observations shown in Column C are all small. The discrepancy for the year 1881 will be discussed more particularly farther on.

The second point is that the indigenous native population of Algeria furnishes, in its history since the French occupation, the first and only example I have so far discovered of a human population virtually completing an entire single cycle of growth according to the logistic curve, and at the same time having definite census records covering practically the whole of the cycle. In all other cases known to me sufficient time has not elapsed since the beginning of the operation of forces which inaugurated a new cycle of human population growth to have the cycle completed, or else in cases like that of France where

the cycle is near its end the early portion was prior to the taking of census records. To find a practically whole and complete cycle of human population growth is a matter of considerable interest in connection with the whole subject of the theory of population growth. The question arises at once as to what were the forces, social, biological, economic or other, which started and carried through this cycle of growth in the isolated homogeneous population with which we are here dealing. Without in the least wishing to be dogmatic in the matter or to go beyond the evidence, I think a reasonable and sufficient explanation is at hand. Algeria is a country of marked physiographic contrasts, which set definite limits to its agriculturally productive potentialities. Where the conditions are naturally suitable for agriculture the soil is excellent. But considerable areas of the country are either (a) desert, or (b) too arid for successful agriculture without being actual deserts in the usual sense of the term, or (c) salt marshes. Algeria had been inhabited for a very long time indeed before 1882, or indeed before 1830. It may fairly be assumed that under the play of natural forces the potentialities of the country in the way of supporting a population in the agricultural stage of civilization, having regard on the one hand to the physiographic conditions and, on the other hand, to the cultural methods and other habits of life firmly established as folkways of the native population, were being rather completely utilized for the support of population by the natives at the time the French took over the country. But the French increased these potentialities in two definite ways. The first was by bringing increasing portions of the arid regions under profitable cultivation by means of irrigation from artesian wells. This beneficent activity has been discussed by many writers, for example Devereux (16, p. 221), Phillipps (99) and Warren (34, p. 63) who says: "In the days of the ancient

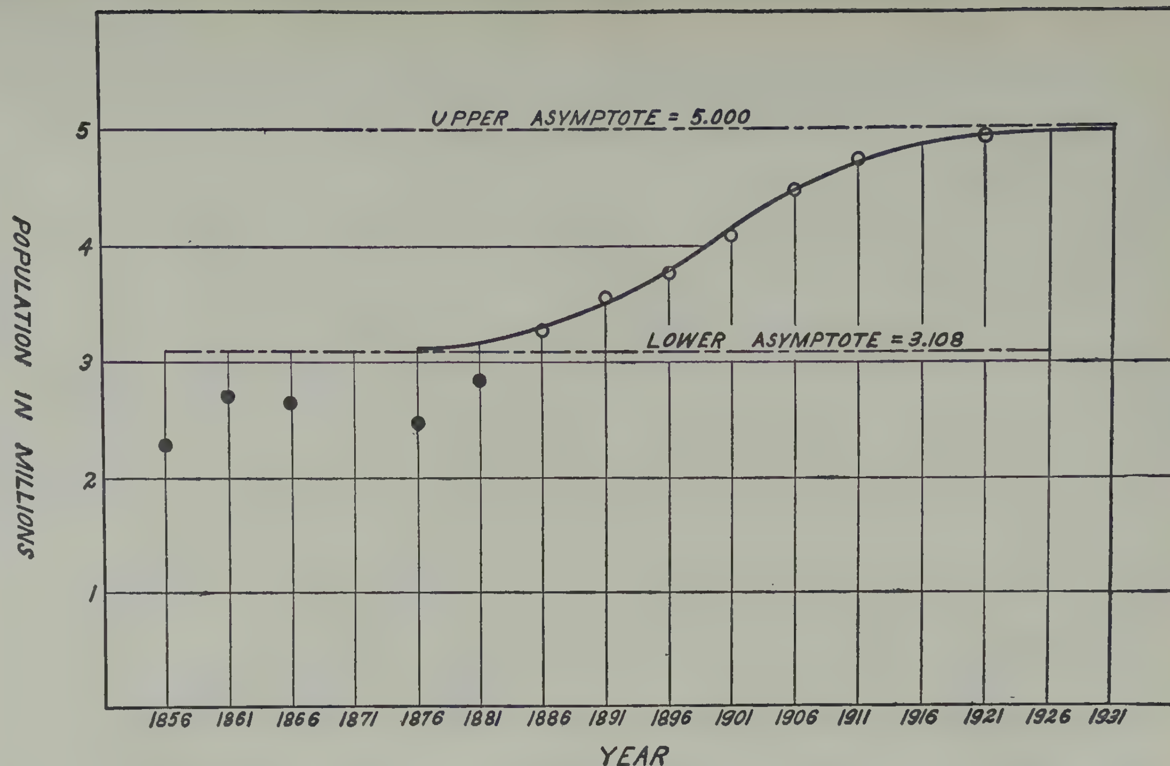

FIG. 16. The growth of the indigenous native population of Algeria. The observations from Appendix Table 13 are plotted as circles. The smooth line is the fitted curve of equation (xviii). For comparison the observations prior to 1886 are shown as solid circles.

wells even these oases were fertile and wonderful; but since the introduction of artesian wells by French enterprise, which tap the hidden flood of the above mentioned subterranean rivers their production has quadrupled and the population of these oases-towns has increased enormously — largely doubtless owing to the attraction offered to labour by the French capitalists, who now for the most part own these wonderful resources of the colony."

The second was by establishing, in ever increasing degree on the average during the period, more settled conditions for the profitable raising and marketing of surplus native agricultural products, teaching the natives improved agricultural methods (*cf.* 7, p. 49, Piquet 100, p. 240, and 5, *passim*) improving the roads, etc. Caix de Saint-Aymour (13), in discussing the rapid growth of the native population between 1872 and 1880 attributes great importance to this element of safety and security which the native enjoyed under the French *régime,* saying: "the natives positively pullulate under our rule. For the first time since the Roman occupation we have given them security. Babies swarm among them like cockchafers under a chestnut tree in the spring." An excellent detailed account of this agricultural development, supported by official statistics is furnished by Labiche (4). To take but a single example he shows that the figure for the production by natives of durum type wheat in 1870 was 4,036,281, and in 1891, 4,833,917 quintals. In 1917–1918 it was 4,699,-993 quintals (48, p. 160). It seems reasonable to suppose that these factors were sufficient to start the native population off on a new cycle of growth, small to be sure in magnitude and comparatively short in duration, but not the less interesting or significant on that account. The fillip to growth appears, in short, not to have been great, but still large enough to produce a definite and orderly effect. The record of what

the French have done in Algeria in the way of improving the natural conditions is a splendidly impressive one, even as reflected in dry and incomplete official statistics. And the good work goes on. In 1921, only three years after the end of the war, Algeria spent three times as much on public works, roads, highways, irrigation, etc., as she did in 1918 (48, p. 132).

The third point concerns the observations as to the number of indigenous native inhabitants of Algeria prior to 1882, in what I have called in Appendix Table 12 the Period of Subjugation. The six observations in this period all lie well below the lower asymptote of the logistic curve which describes the growth of the population in the Period of Citizenship. This fact might at first thought be supposed to be a serious reflection on the adequacy of the logistic curve in this case, on the ground that the lower asymptote of (xviii) was greatly too high. But the accessible evidence suggests that an alternative explanation is possible, and indeed more probable. It seems reasonable on general grounds to suppose that for some time, perhaps a long time, prior to 1830 the native population of the region which is now Algeria had been fluctuating up and down about the upper asymptote of a completed cycle of growth. When in 1856 the French started to enumerate the native population three factors influenced profoundly the magnitude of the counts obtained. The first was that in the period from 1830 to 1856 a by no means inconsiderable portion of the previously upper asymptotic population had been killed off by the French themselves in the business of establishing their position in the country. Time had not sufficed for the replacement by natural processes of reproduction of those lost. The second was that probably there had been a sensible amount of migration of natives into the neighboring territories of Morocco and Tunisia. The third, and perhaps most im-

portant, fact was that in 1856, and on up to the early eighties, the native population was not in fact completely and permanently subjugated. The French were actually at war during these years with larger or smaller portions of the native population, intermittently to be sure but still frequently. Under these circumstances it is not unreasonable to suppose *a priori,* and is known to have been the fact, that there was widespread distrust and suspicion among the natives of the French and their motives. Leger (46), writing in 1866, says on this point (and the italics are his) (*loc. cit.* p. 102):

"I am not speaking of the Arabs who have settled down in our cities. That group never causes any serious difficulty except to the police. It is generally insolent, curses God, gets drunk, and, in consequence, regards itself as French. But beside this misguided group — which we have not made more immoral but in which we have implanted new vices — there exists another which merits our full care. *Always rebellious to our authority — at heart, in any case — this part of the population has remained completely Arab and free of all habitual contact with us.* This, the soundest, the most numerous, the richest, the most influential, *the most recalcitrant, and the most mobile,* this is the group whose heart and spirit we must convert to the French cause; this is the group we must reach and *win over.*" Such a situation negatives the possibility of an accurate census count of the natives being made. The numbers obtained were bound to understate the actual numbers.

Labiche (4, p. 46) says regarding the early native population data: "Les chiffres ne présentent aucune garantie d'exactitude; ils donnaient seulement une idée approximative de l'importance de la population indigène." After 1871 this aspect of the matter steadily improved, and we see the counted and estimated number of natives, as given in the figures of

Appendix Table 12 steadily increasing. The very low figure of 1871 corresponds precisely in time with the great insurrection of Kabylia.

The fourth point to be considered is the future native population predicted by the logistic curve given by equation (xviii). The upper limiting population of this curve is 5,000,000. The recorded native population in 1921 was 4,924,938. It is therefore evident that if equation (xviii) is to be regarded as adequately describing the current cycle of growth of the Algerian native population, it has only to increase by 75,062 souls before reaching the asymptotic condition. Supposing this to be true, for the moment, it would not necessarily mean that this might not become at some future time larger than 5 million. It merely says that so long as the same general set of factors, racial and environmental (including economic, social, and biological as well as physical) as have operated during the period from 1886 to 1921 continue to operate, the probable upper limit to the native population is about 5 millions. If a new set of social, economic, or other forces, favorable to a larger growth of the native population, come into play it is to be expected that the population will respond, probably by starting off on a new cycle, just as it did after 1871, as has already been shown, but possibly by pushing up the limiting value of the old cycle to a higher figure.

IV

Before finally accepting the upper limiting value of 5 millions for the present cycle of growth, however, some further consideration of the matter is demanded. In the first place, in taking only the data from 1886 on from which to determine the constants of the cycle of native population growth which has obviously been going since the early seventies, after the

last great rebellious outbreak, I was trying to achieve the greatest degree of purely statistical accuracy possible, without regard to any other considerations. As has already been pointed out, it is not until the 1886 census that the figures for the native population of Algeria can be regarded as preponderantly counts and not estimates. But, on the other hand, there is plenty of evidence that the 1881 census was closely approaching the accuracy of the later ones. It should be remembered that it was early in 1882 that the law giving civil status to the native population was passed. This political boon was only granted to the natives after a period of essential tranquillity nearly 10 years long had demonstrated their worthiness for it. While the native population in 1881 had not numerically recovered from the repressive measures of 1871, and on that account is not a truly representative point for the determination of the constants of the growth cycle, still it was thought worthy of inclusion as the basis of a second trial approach to the mathematical description of the growth of the native population.

So then a logistic curve was fitted to 8 successive census figures beginning with 1881. I shall not take the space to give the details regarding this graduation. It suffices to say that, taking the origin of the curve at 1881 the upper asymptote worked out to be 5,399,000, and the lower asymptote 2,541,000. The point of inflection was at approximately December 10, 1898, or about 8 months earlier than that of equation (xviii). The agreement between theory and observation was again close. The mean percentage deviation, regardless of signs, was found to be 2.02. The net deviation having regard to signs was in total + .57, and per ordinate fitted + .07. The corresponding figures for equation (xviii) are: Mean error on all 8 points regardless of signs 2.10. The net deviation having regard to signs was in total + 11.80, and

per ordinate fitted + 1.44. The worse showing of equation (xviii) as compared with the second trial curve is solely due to the 1881 observation which did not enter into the computation of the constants of equation (xviii). This 1881 census figure, as has been pointed out, is probably lower than it would have been had the Kabyle insurrection of 1871 not occurred. This low observed value is probably the result of two special causes, namely military losses in 1871 not fully recovered from, and incomplete counting. There is, under these circumstances, no slightest reason either to expect or demand that equation (xviii) should hit this 1881 point with accuracy. Even the second curve which included this point was unable entirely to do so, because of its abnormal value, due to the special causes pointed out.

The second curve predicted a native population of Algeria in 1926 of 5.17 millions, in 1931 of 5.25 millions, and in 1936 of 5.30, leaving only some 99,000 souls to add between that and the asymptotic population. I am inclined to believe that these predictions are, on the whole, more probable than those given by equation (xviii). In this connection it will be noted that equation (xviii) hits the 1921 observation much better than did the second curve, and it is in considerable degree the weight of this end observation in the series which damps off the curve of equation (xviii) so heavily and rapidly, and thus leads to the somewhat low upper asymptotic value of 5 million. Now there is some reason to believe that the recorded value for the native population in 1921 is lower than it ought to be, as result of the world war of 1914–1918, and of subsequent migratory movements consequent upon it; or, to put the case more accurately, is lower than it probably would have been had there been no war in 1914–1918. In short, I am disposed to believe that the second trial curve is really nearer the normal, or true and undisturbed, course of the growth of

the native population of Algeria, when it passes 1921, than is either equation (xviii) or the observation recorded as of that date.

Evidence that the 1921 figure for the native population is abnormally low is afforded by a study of recent migration data. In the first place it is known that since the war there have been a good many natives in France itself. On this point a recent communication by Wiegand (49) is pertinent. Writing from St. Cloud on the general subject of the present foreign population of France, after enumerating resident foreigners of European origin, he says that there are "more than 100,000 colored colonials from Morocco, Tunis and Algiers, concentrated principally in Paris and its environs." He means, of course, Tunisia, not Tunis, and Algeria not Algiers.

An examination of recent migration statistics supports strongly the idea that the native population counted in 1921 was below the true value. From the latest official statistical document for Algeria (48) Table IV has been constructed, in continuation of Table II *supra*.

TABLE IV

MIGRATORY MOVEMENTS BETWEEN ALGERIA AND THE EXTERIOR

Year	Total net migrants *A*	Total net migrants between (*a*) Algeria and (*b*) Morocco and Tunisia together, by both water and rail *B*
1916	− 20,692	+ 6,366
1917	+ 9,595	+ 14,704
1918	+ 7,463	+ 22,488
1919	+ 94,576	+ 28,653
1920	− 23,331	− 27,515
1921	− 30,459	− 43,986

It is, of course, impossible to reconstruct from these figures a complete picture of what has happened, but it seems fairly clear that we have to do here mainly with troop movements consequent upon the war and its *sequelae*. Column A of Table IV gives the total net migration figures, the plus sign meaning as before that the inflow of persons to Algeria exceeded the outflow, and the minus sign that the outflow exceeded the inflow. The figures in Column A include all means of transportation, and migration to and from all countries and of all races. Plainly enough in 1919 there was a great movement of persons back from France to Algeria. The war was over.

Column B relates much more exclusively to the native population, though not entirely so. It presents the facts regarding the interchange of population, by all means of transport, land and water, between Algeria on the one hand, and Morocco and Tunisia taken together on the other hand. Obviously this movement will have been mainly of native population. This deduction is supported by examination of the detailed statistics regarding transportation by railroad, where the original data are separate according to the class of accommodation used (I, II, or III). Class III travel enormously preponderates, and may safely be taken to have been almost exclusively of natives.

What Column B of Table IV shows is that in 1920 and 1921 there was a relatively marked movement of natives *out of* Algeria. This, of course, means that the 1921 census count of natives in Algeria was lower than it would have been had this emigration not occurred.

Taking all the evidence together the conclusion seems certain that the 1921 point as depicted in Fig. 16 must be regarded as below what would have been the true value if

the normal populations had not been disturbed by the war and its after effects.

There is one point in regard to Table IV which ought to be explained because it seems at first glance an impossible sort of paradox. The reader may at first find it hard to understand why, with a net *total* excess of immigrants in 1917 of only 9,595 there was an excess of immigrants from Morocco and Tunisia *alone* of 14,704. But this is quite correct. In that year there went from Algeria by boat to all other countries than Morocco and Tunisia (chiefly France) 209,642 persons, while there came to Algeria, by the same means, from all other countries except Morocco and Tunisia, 204,533, making a net *loss* on this portion of the migratory business of — 5,109. But if we subtract 5,109 from the 14,704 excess immigrants from Morocco and Tunisia we have left + 9,595, which is precisely the number set down in Column A for 1917, as the total net excess. So the apparent paradox is explained.

Turning now to the question of extrapolation at the front end of the curve to years prior to 1881 it was found that the second trial graduation gave, as was to be expected, a lower asymptotic value which probably more nearly accords with what was the average, running level of the native population prior to 1830 when the French began occupation, than does equation (xviii). It is believed, however, as has already been pointed out, that every one of the officially recorded figures for the native population before 1881 is probably below what was the true upper asymptotic value for the previous cycle of growth of the population.

There was next taken one further and final step in the examination of the growth of this native population. A logistic curve was fitted to all the data from 1856 to 1921, inclusive. It has been pointed out above that the census records prior to 1886 are in greater or less degree inaccurate,

and the country was in a disturbed state. This fact is plainly reflected in the rather wild fluctuations of the figures prior to 1886 around their trend line, as compared with the smoothness and regularity with which the trend is followed from 1886 on. On account of the roughness of the data prior to 1881 it was decided to smooth them graphically before fitting the whole series by least squares. Doing this by the standard method, and then fitting by least squares the logistic curve to the whole series of 13 points, the following equation was obtained.

$$y = 2.238 + \frac{3.141}{1 + e^{1.2059 - .4232x}}, \qquad \text{(xix)}$$

As before, the unit of x was taken as 5 years. The lower asymptote is at 2,238,000 and the upper at 5,379,000. The point of inflection was approximately in the first half of March, 1895, a little more than 4 years earlier than that of equation (xviii).

The values of the several ordinates of equation (xix) are shown in Columns D and E of Appendix Table 13, and for the whole range of observations, as the last column of Appendix Table 12. The graduation is clearly an excellent one both from the standpoint of mathematics and common sense. The mean percentage error, regardless of sign, over the 8 points 1881–1921 is 1.81. The net percentage deviation having regard to signs is, in total, + 7.11, and per ordinate fitted + .89.

The curve is shown graphically in Fig. 17.

The first point to be noted about this curve (xix) is that its general form is only slightly different from that given by equation (xviii). In short, whether we take only the census observations which can be regarded as reliable counts, or whether we take every official estimate and count of the native

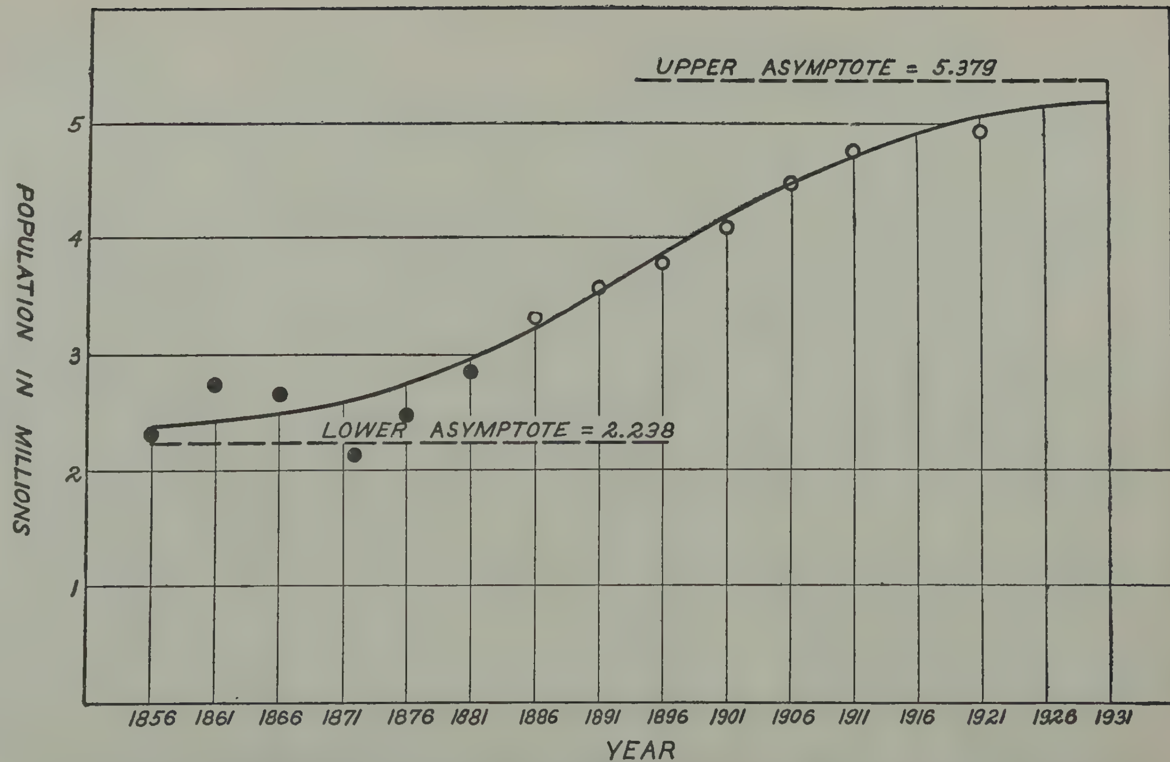

FIG. 17. The growth of the indigenous native population of Algeria. The observations from Column A of Appendix Table 12 are plotted as circles, solid before 1886 and open thereafter. The smooth curve is the graph of equation (xix).

population which has been made since French occupation of the country, we come to very similar logistic curves. The upper limiting population is 379,000 larger in (xix) than in (xviii), and the lower asymptote from which the present cycle starts 870,000 smaller. It is highly probable that both of these values from equation (xix) are better approximations to the truth than the corresponding estimates given by equation (xviii). Regarding the population in 1830 Laurie (51) has the following to say (p. 24): "15,000 Turks were, roughly, the garrison and the governing race. The 'governed' amounted to some 3,000,000 souls." This is, of course, only an estimate and is probably somewhat, though not greatly, too high.

The upper asymptotic population of equation (xix) is still probably somewhat too low, because of the considerable effect of the 1921 observation in damping off the curve, and the further fact already pointed out, that this 1921 count is almost certainly abnormal. It seemed of some interest to see what would happen if an attempt were made to correct this 1921 observation in allowance for the unusual migratory movements, and a new logistic curve then fitted. After careful study of all the available evidence on this question of war and post-war migration it was estimated that perhaps there were about 80,000 fewer natives in Algeria at the time of the census count of 1921 than would have been there had there been no disturbance of the course of population growth by war. Adding this to the observed 1921 figure, leaving all other observations as in Appendix Table 12, and fitting a new logistic to this altered series, we get an upper asymptotic value of 5,416,000, or only 37,000 higher than that predicted by equation (xix), a figure well within the expected error of census taking. There seems to be no valid reason to suppose that the 1921 observation is in error (in defect) by an amount

substantially greater than 80,000. So we are rather forced to conclude that the upper limit of the current cycle of growth of the native population of Algeria will be somewhere in the near neighborhood of 5.4 million persons. And this value seems, after very careful study of a wide range of statistical data about Algeria, reasonable.[3] For some years past there has been no marked or definite increase in general agricultural production, except in the case of dates, where the irrigation developments show rapid and continuing results. The flocks and herds of domestic animals, especially those owned by natives, were badly depleted by the war and it will take some years for them to recover their pre-war status.

The future native population as predicted by equation (xix) is shown in Table V.

TABLE V

FUTURE GROWTH OF NATIVE POPULATION OF ALGERIA AS PREDICTED BY EQUATION (XIX)

Year	Predicted native population in millions
1926	5.162
1931	5.234
1936	5.282
1941	5.315
1946	5.337

Several French students of the colonial situation have at different times made predictions of the future growth of the native population. It will be of interest to examine these estimates in the light of what has actually happened in this

[3] I cannot take the space for a detailed statistical demonstration here of the evidence on which this and following statements regarding agriculture are based, but will simply refer the reader to the official statistical publications of the Algerian government, (for example 48).

cycle of growth, and what seems likely to occur in the near future at any rate.

Caix de Saint-Aymour (13) quotes some population predictions made by Tirman in one of his official reports to the *Conseil supérieur*. These predictions were based upon the figures of 1866 and 1886. They were as follows, for the native population:

1906	5 millions
1926	7 millions
1946	10 millions

At this latter date there were to be 1,280,000 French. Caix de Saint-Aymour, writing in 1891 feels these predictions to be too large and says that "heureusement pour nous, la nature n'obéit pas toujours à ces lois mathématiques." It would seem a super-politeness which would imply that mathematical laws had much to do with Tirman's prediction. Apparently he failed, as many forecasters of population have done, to allow for anything in the nature of a damping effect on growth entering into the situation after a time. This failure always strikes one as strange because economists have long been familiar with this concept and also with the fact of diminishing returns.

Labiche (4, p. 46) writing in 1896, predicts on the basis of the growth from 1886 to 1891 that the native population in 1911 will be 5,028,478. This figure is more than a quarter of a million higher than the native population in 1911 really was, and indeed is higher than was the population actually attained 10 years later in 1921. Again anything in the nature of a damping factor appears to have been overlooked.

Casserly (14, pp. 249–252), writing in 1923, discusses the probable future population at considerable length but not in

any very precise statistical manner, basing what he has to say in part on a paper by Peyronnet which I have not been able to locate. He predicts a native population of 40 millions at about the year 2000. It is not clear whether he means this to apply to Algeria alone or all French North Africa, including Morocco and Tunisia. But inasmuch as the native Mussulman population of Tunisia is less than a half that of Algeria, while that of French Morocco is only slightly larger than Algeria's, it seems plain that in estimating the soundness of a prediction which so far exceeds anything which can reasonably be forecast from any events which have happened in the past, or phenomena which exist at present, it will not make a great deal of difference in the judgment reached whether one, two, or all three of the colonies are considered to be included. This estimate of Casserly's, in short, cannot, in my judgment, be taken seriously.

Devereux (16) is somewhat more conservative in her population predicting. She says (p. 260): " In that future when all these diverse Latin elements will have been merged in the Algerian race, what attitude will it adopt towards the native multitudes at its gates? By that time the question as to French and foreign numerical proportions will be dwarfed by the infinitely greater fecundity of the native population. In the census of 1911 the Arabs and Berbers, or Kabyles, counted together, reached the figure of 4,740,526, which represents an increase of 322,468 since 1906. Assuming that the total population augments in the same degree, it is improbable that the number (p. 261) of Europeans in Algeria will exceed 1,000,000 by the middle of the century, as against 8,000,000 natives."

Regarding this prediction of a native population of 8,000,000 in 1950, the following may be said. In the first place the " infinitely greater fecundity of the native population " is not

in accord with the statistical facts. In the 14 years 1901–1914 inclusive the *mean* annual birth rate per 10,000 inhabitants of the *Territoires du Nord* was 296.0 for the European population and 294.3 for the native Mussulman population. The "infinitely greater" turns out to be slightly *less!* In 7 of these 14 years the native birth rate was less than the European, and in one year was the same, leaving only 6 years in the period in which the natives had any higher birth rate than the Europeans (*cf.* on this point Appendix Table 17). In 1921 the native birth rate per 10,000 inhabitants in the *Territoires du Nord* had dropped to 215.7 while the corresponding rate for the European population was 258.6. All of these birth rates just discussed relate to live births.

In the second place, Devereux's prediction, like all the others, neglects the action of any future damping factor, in its assumption that the rate of growth exhibited in the period 1906–1911 will continue indefinitely to manifest itself undiminished.

Taking all the available evidence together it appears to me unlikely that, during the next 20 years, which is as far ahead as I should care with any seriousness to predict, the native population will grow much if any beyond the upper asymptote of 5.379 millions predicted by equation (xix). The agricultural statistics of the country strongly support this view, as do also the birth and death rates which will be more particularly discussed in later chapters. Testimony in the same sense is offered for one part of the country (Kabylia) by Wilkin (25), who says (p. 110): "Presently will come the question of an increased population already attested by these same outlying settlements. What is to be done with superabundant Chawia? This country, never a rich one, can hardly be made to grow more than it does at present. Already the Chawia practice farming almost on the Chinese system.

Every inch of fertile ground is irrigated and manured and fenced and carefully tended. The evil days of semi-starvation for many cannot be long averted by scratching the barren hills and trusting Providence to provide once every few years a rainfall sufficient to produce a scanty crop of barley."

The agricultural limitations of the country in general are well described by Ducrot (45) in the following words: " Besides, Algeria today is just what it was in the time of Sallust and in the time of Constantine. In its ensemble it is a region of mediocre fertility, without navigable waterways, large forests, and even over immense stretches, without brushwood or any other fuel; a region broken up by deep ravines which, according to the season, are torrents of water or beaches of dry gravel making it very difficult to establish good means of communication.

" On his rough, uneven soil the farmer has to fight not only against the difficulties that he meets in other climates but also against disastrous plagues which only too often come to destroy the fruits of the hardest toil and demolish the fairest hopes, — factors like the irregularity of the climatic phenomena, exceptional dryness, torrential rains, in certain regions snow and ice; floods, grasshoppers, flies, epidemics, epizoötics, and earthquakes."

In leaving this section of the discussion of the vital statistics of Algeria it needs to be pointed out once more that the predictions of the future growth of the native population may at any time be altered by the entrance into the situation of new economic or social factors, of a different sort to those which have operated during that past period which equation (xix) covers. The population may be stimulated to start upon a new cycle of growth, or slighter, but still in kind new factors, may alter somewhat the upper limiting value of the present

cycle. Such a factor which might conceivably have stimulated population growth was the law of February 4, 1919, which gave political rights to certain portions of the native population (*cf*. Fribourg (7)). This law may still produce such an effect, but as yet there are no signs of it.

CHAPTER IV

THE MORTALITY OF THE NATIVE POPULATION OF ALGERIA

THE same laws as those of Paris are applied to the European population of Algeria in regard to the registration of marriages, births, and deaths. A law of March, 1882, created a civil status for the native population, as has already been pointed out. Since then it has been equally obligatory for that population to declare its births and deaths. These declarations are registered in due form according to the French law. The marriages of the native population are also registered. The registration is naturally not perfect in the more remote parts of the country (a fact also true of these United States). But it appears that the unreliability is not great except in the Territories of the South and a few other regions. In general Bunle (1) states that the registration figures " donnent une limite inférieur des nombres des actes de l'état civil dressés pour les Musulmans." In the *Territoires du Nord,* to which we shall confine our attention in what follows, there is no reason to suppose that the gross registration of deaths (neglecting for the moment such matters as cause of death) of the native population is not approximately as accurate as that of any rural population with a considerable primitive native element in its composition. Furthermore it is sure that there is very little secular change in the quality of the registration of the mortality of the native population, and that such change as there is is in the direction of improvement. That is to say, such tendency as exists will have been in the direction of a

more complete registration of the native deaths in 1914 than in 1901. Any other assumption would be an unwarranted reflection on the efficiency of the *Statistique générale de l'Algérie*, and upon the system of colonial district physicians (*cf.* 37, 23, 35, 47) one of whose chief duties is the first step in the registration of deaths.

Let us now consider certain social facts. The population of Algeria of European origin is as we have seen, largely French. They are mainly urban dwellers. They have, as is well known, transferred in large measure French culture and organization to the cities of this colony. They pay attention to sanitation, hygiene, and public health, and live under the benefits of modern public health knowledge as the people do in France. They are in no sense living under pioneering conditions but under highly sophisticated ones. Algiers, including its environs, is in fact a health resort, noted for its beauty and healthiness.

On the other hand the Mussulman population of Algeria comprises people of ancient and different cultures. The Arabs and Berbers are both noted for the firmness with which their folkways are established and the conservatism with which they resist any attempt to alter them. Morell (95, p. 315) says of the Arabs: "Of all the nations on the face of the earth, these are probably the greatest conservatives." Sir Richard F. Burton found even the most intimate habits of daily life of the Arab of the Arabian Nights and of the present day essentially identical. Now the fruits of European public health doctrines and education can scarcely be thought to play any large or direct part in the folkways and mores of the Arab or Berber. His notions of sanitation, cleanliness, personal hygiene, and medicine are all his own. That they are different from those which govern such matters in the civilization of western Europe or in our civilization has been

shown in great detail in Doughty's "Arabia Deserta" (17), and in the accounts of many other travellers in Arab countries. Finally it is to be noted that rather more than two thirds of the native Mohammedan population of Algeria derive their living from the practice of agriculture, and therefore do not share even indirectly in the sanitary benefits of French urbanization.

Devereux (16, p. 141) says: "The Arab, like all the poorer classes of Orientals, is totally devoid of hygienic knowledge; and as his religion leads him to ascribe all afflictions of the flesh to the will of Allah, it is not easy to induce him to acquire habits calculated to prevent the spread of illness in the *douars*."

Harrison (110) offers similar testimony. He says (p. 160): "There are some things which an Arab sheikh does not do. He takes no interest in the promotion of public health. It would not occur to him that such an activity came within the functions of a ruler." And in another place the same writer, in discussing the attitude of the Arab to those who govern him, makes the following illuminating statement (pp. 173–174): "He [the Arab] wants the government that allows him the best food to eat and the most nearly decent clothes to wear, that makes it possible for him by effort and economy to live in a house that will at least keep out the sun and the rain. He wants more than this. He wants the liberty to go where he pleases without interference, and the permission to be whatever sort of Mohammedan he desires, *and last but not least, he wants no annoying interference with his liberty for sanitary and police purposes*" [my italics].

Bertherand (50, p. 305–306), whose treatise is the standard work on medical matters concerning the natives in the region under discussion, says regarding the relation of the Mohammedan religion itself to sanitation and health: "that the

influence of fatalism on the production and disastrous termination of sporadic and epidemic diseases is an undeniable fact. It sets the most narrow limits to all activity of the mind; it paralyzes deplorably any live forces that intelligence might put forth to repel or prevent many dangers both physical and moral, and on the other hand, abandons the noblest faculties to the constant triumph of the material and sensual."

With these considerations regarding the attitude of the natives toward health and disease in mind, let us examine the course of mortality (deaths per 10,000 inhabitants) of the two moieties of the population (European and Mussulman) of the *Territoires civils du Nord* of Algeria from 1901 to 1914 inclusive (Bunle, *loc. cit.* p. 354). Appendix Table 14 gives the data, and also for comparison the death rates of France, the United States Registration Area, and England and Wales for the same years (taken from Mortality Statistics, 1920, United States Census Bureau, 1922, p. 16). The data stop with 1914 because of the disturbing effects of the war upon the statistics after that date.

The death rate curves of Appendix Table 14 are plotted in Fig. 18 on arithlog paper, so that the *slopes* of the lines may be accurately comparable visually.

The diagram plainly indicates that the decline in the death rate has been substantially the same in this 15 year period in the two moieties of the Algerian population. The absolute death rate is roughly 10 per cent higher in the Mussulman population. But it is decreasing just as fast as is that of the European population. Furthermore it appears that from 1904 on the death rate of the native Algerian population declined quite as fast, or a little faster, than that of either England and Wales or the Registration Area of the United States, and distinctly more rapidly than that of France. The dip in the

death rate curve of 1903, with higher rates in the years on either side (1902 and 1904) appears to have been practically a world-wide phenomenon, and only more marked in degree in Algeria than in the other countries shown in the diagram.

In order that a more accurate comparison may be made of the slopes of the death rate lines of Fig. 18 the data of Appen-

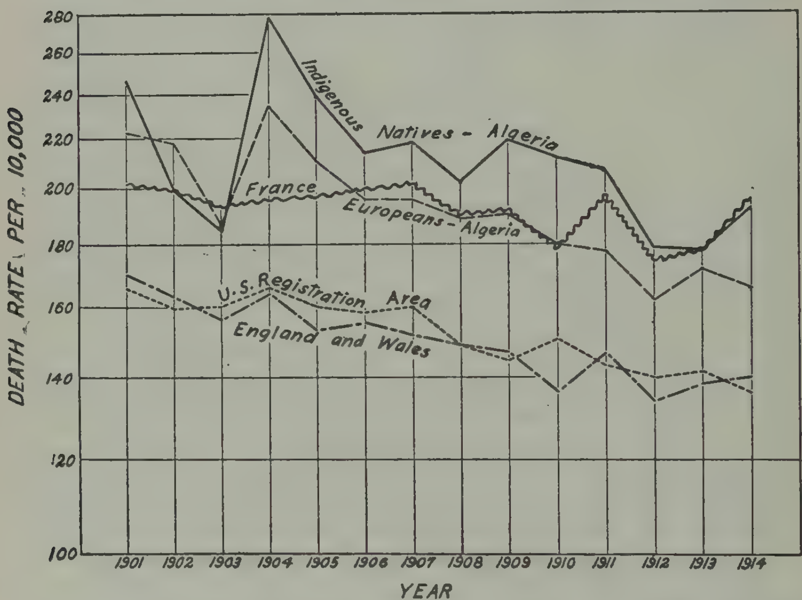

FIG. 18. Course of the death rates from all causes in Algeria. Solid line, Mussulman population. Dash line — European population. Territory of the North only. Corresponding death rates for comparison are: France, crinkled line; United States Registration Area, dotted line; England and Wales, dot dash line.

dix Table 14 have been fitted with straight lines by the method of least squares. The equations of the fitted lines are as follows, y denoting death rate and x years:

European population of Algeria	$y = 226.3 - 4.503x$	(xx)
Mohammedan population of Algeria	$y = 238.4 - 3.567x$	(xxi)
France	$y = 200.2 - 1.163x$	(xxii)
United States Registration Area	$y = 168.8 - 2.255x$	(xxiii)
England and Wales	$y = 167.6 - 2.393x$	(xxiv)

In these equations the coefficients of x determine the slopes of the lines. Since, however, the lines start at different absolute values these coefficients cannot fairly be directly compared as absolute numbers. They must first be reduced to relative numbers. This may be done in the following way. Writing the equation of a straight line as

$$y = a + bx \tag{xxv}$$

we may take as a relative index of slope the constant 100 b/a. Doing this for equations (xx) to (xxiv) inclusive we have the following results:

		Slope Index 100 b/a
European portion of Algerian population	=	2.0
Indigenous native Algerian population	=	1.5
France	=	0.6
United States Registration Area	=	1.3
England and Wales	=	1.4

It is seen that of the five populations compared the relative slope of the death-rate decline has been actually somewhat *greater* in the indigenous native population of Algeria than in any of the other populations except that of the French in Algeria. The difference between the slopes of the native line on the one hand and those for the United States Registration Area and England and Wales on the other hand, are obviously too small to be significant. All that can really be said is that the death rate of the native Algerian population has declined in these 14 years as fast as has that of the other two countries named.

The trends of these fitted straight lines are shown graphically in Fig. 19.

It is of some interest to note that according to figures presented by Hoffman (57) the death rate from cancer appears to be declining amongst the native population of the city of Algiers, while in the European population it seems to be stationary or slowly rising. The figures are as follows:

Year	Rates per 100,000	
	European	Native
1914	64.3	12.5
1915	57.5	15.0
1916	48.7	12.5
1917	54.3	5.0
1918	56.3	5.0
1919	55.6	7.5
1920	58.7	12.5
1921	66.7	6.2

It is to be noted that the data relate to the disturbed years of the war and post-war period. I doubt if they can be taken at their face value.

It is important to consider carefully the question as to the extent to which the decline in the native death rate can be attributed to public health measures. While it seems improbable on *a priori* grounds, for reasons already stated, that such measures can have played any considerable rôle, nevertheless it is to be remembered that the *a priori* logic of an objective situation may be very far indeed from the real facts. Caution and fairness demand that all available evidence be dispassionately marshalled, and a judgment then reached. This I have tried to do, after studying the literature available on Algeria in the accessible libraries.

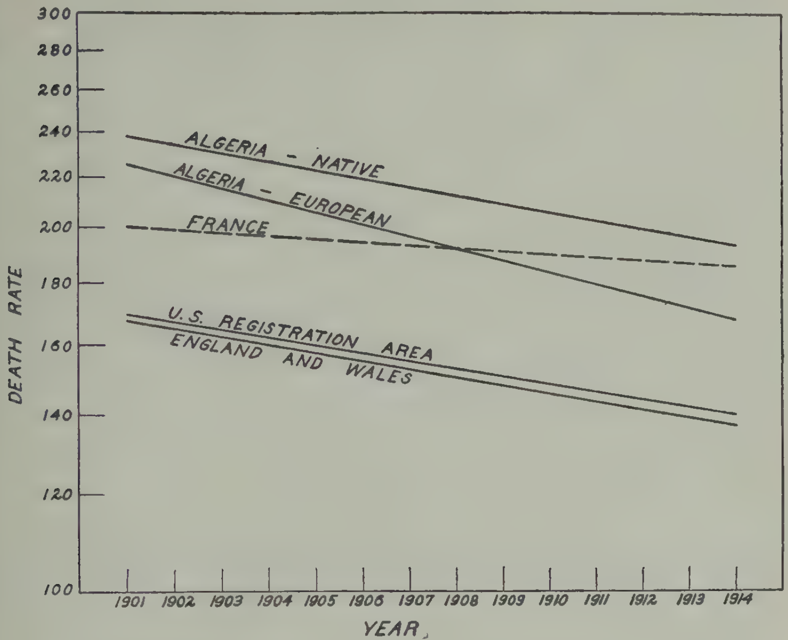

FIG. 19. Straight lines fitted to the death rates of various populations, 1901–1914 inclusive.

As might be expected the evidence is at first glance somewhat conflicting. A good many of the French who have written about Algeria have been concerned to defend the French colonial administration, either against criticism at home, or from other countries, or from the Mussulman natives, and have been disposed to depict all enterprise under French guidance as functioning with the greatest efficiency. On the other hand, the critics of the French have produced a mass of *ex parte* testimony on the other side. Finally, those of other nationalities who have discussed Algeria have frequently been partisans, and written accordingly, or have been concerned merely with artistic, archæological, or other special aspects of

the country. So then what one is compelled to do is to try to sift out of this welter of conflicting and irrelevant material a clear picture regarding the point of present interest.

Let us begin the discussion with what is perhaps the most fundamental element in all public health work, namely *education.* It is generally admitted, indeed so far as I am aware has never been questioned, that one of the most important elements in the promotion of public health is the general state of public education. In an ignorant and illiterate population it is extremely difficult to make progress in health matters. Furthermore it has been definitely shown (54) that in the Registration Area of the United States there is a significant positive correlation between the general death rate and the percentage of illiteracy in the population.

It may, then, be taken as pertinent to inquire into the state of public education of the indigenous native population of Algeria both absolutely and relatively to the European population. On this point there is, and really can be, no serious divergence of opinion. The official statistics accurately exhibit the situation. The essential data derived from (48) are digested and condensed in Appendix Table 15.

It is at once evident from Appendix Table 15, without any special treatment of the data, that the native Mussulman population has in proportion to its numbers far fewer individuals in schools than any other element in the total population of the country. The magnitude of the disparity in this regard is sufficiently well shown by comparing the figures in the last column of Appendix Table 15 (1920–1921) with the population counts for the same racial elements according to the 1921 census. The results are shown in Table VI.

Two things strike one from an examination of Table VI. The first is the meagerness of the representation of the Mussulman population in primary and secondary schools in propor-

TABLE VI

RELATIVE NUMBERS OF DIFFERENT ELEMENTS OF THE ALGERIAN POPULATION IN PRIMARY AND SECONDARY SCHOOLS IN 1920–1921

Class of School	Percentage of total population in designated schools [1]			
	French	Israelites	Mussulmans	Foreign
Primary education:				
Écoles primaires et maternelles	13.5	21.1	0.88	11.5
Écoles normales............	.06	.03	.001	......
Secondary education:				
Établissements publiques...	1.2	2.6	.009	.08
Établissements libres.......	.15	.005	.0004	.006
Total......................	14.9	23.8	.89	11.6

[1] These percentages are not entirely exact because of small differences in racial classification of general population and of school children, but they sufficiently approximate the truth for the present purpose.

tion to their numbers. The second is the greater representation of the Israelites than of the French in the schools which the latter have established. In this result we see probably another example of what is everywhere recognized as a Jewish racial trait, namely keenness for education. Another possible factor in this case, of course, is that there may be a larger proportion of the Israelite population than of the French in the lower age groups.

So far as concerns the Mussulman population only one explanation of the observed result is possible. They are not being educated in anything remotely approaching the extent to which the other elements of the population are. Two sets of reasons are responsible for this situation. In the first place the Arab is not in the least keen to have his daughters go to school, and only sporadically and not more than mildly inter-

ested in whether his sons do. On this point Casserly (14, p. 57) says: " Education is not compulsory for native children; and the Arabs, while usually strongly opposed to it for their daughters, are not avid for it for their boys, although the Kabyles — that is, the Berber inhabitants of Kabylia — are." Also the French have not been tremendously enthusiastic about educating too freely or extensively the native population. Devereux (16, pp. 138 and 139) in speaking of what the French have done for the native population of Algeria says: " But of the various levers which enable a race to rise the most potent is that of education, and until today educational facilities have been offered to the Arabs of Algeria with a very sparing hand." Bach-Hamba (41) criticises the French for not having provided more liberally for native education. He is obviously a somewhat disgruntled partisan critic, but the same point has been made by French students of the Algerian problem, notably Gennep (20) who says (p. 191): " We have partially civilized Algeria from a material point of view; we have done almost nothing from the intellectual point of view, which is the most important." Also further on (p. 192) the same author makes the following suggestions as to what has not been done and ought to be done relative to the natives: " To develop their material and intellectual needs, to impose upon them strictly the requirements in hygiene and equality of the sexes which are beyond their present understanding, and especially to be clear that it is not by gentleness, by coaxing, or by narrow-minded petty politics that the native peril will be destroyed."

Altogether I think we are bound to conclude that the basic foundation for sound and effective public health efforts which is laid by a good general education of the population is seriously lacking in the case of the natives of Algeria.

The state medical and public health service in Algeria was

quite naturally and properly built up by the French in the interests of their own colonists. In the earlier years, as has been shown in the preceding chapter, the relations of the French with the natives were not generally of a character to lead to the wide-spread extension of benevolent enterprises among the latter. An anonymous writer (37) on the conditions in Algeria in 1877 speaks particularly of the medical service for the colonists, and states that at that time there were 130 colonial physicians maintained by the state, each having charge of a *circonscription médicale*. This writer says that the service had never failed up to that time even during epidemics, so far as concerned the French population. But Cambon (55) in his interesting and valuable account of his progressive administration of the colony mentions (p. xiii) a cholera epidemic in 1864 which, with the immediately following famine, " faisait périr un grand nombre d'indigènes."

Leger (46) writing in 1866 said (p. 44): "It would be excellent politics, therefore, to introduce *nuns*, in every locality where there is an Arabian office, to visit the sick of the tribe as often as possible. Their influence would be considerable over both men and women, but especially over the latter."

Writing still earlier Vaillant (35) in his official report to the Emperor says that before his time the medical service had never been properly organized, nor functioned with " la régularité désirable." With the modesty appropriate to an official reporting his acts, he states that under his administration the service had been well organized and was furnishing gratuitous services to both colonists and natives when they were indigent. From his account the chief duties of the colonial medical officers at that time appear to have been to vaccinate and to register deaths and nosographic statistics. The last paragraph of his account shows pretty clearly that the

preventive medical service really functioned only for the colonists.

The first hospital for natives was established in 1874 at Attafs. With this single native hospital the case rested for 20 years, when in 1894, during M. Cambon's administration, a second native hospital was opened at Ouarqen in Kabylia. The next year a third was opened at Arris, soon followed by two more, one at Biskra and the other at Ghardaia. Since that time the policy of the Algerian government has been to operate "infirmaries" for the natives, because they are less costly to maintain than hospitals. They are said by Colin (56) to have "rapidement multipliées, notamment sous le gouvernement de M. Jounart, et rendent de très grands services." This author gives an excellent account of the whole history of medical service for the natives. Cambon also during his administration inaugurated a special medical service for native women, with female physicians, especially to look after obstetric needs.

What Cambon has to say regarding his motives and viewpoint in developing medical service for the natives is of interest, and worth quoting as throwing light on the conditions relative to the health of the native population and the possibility of effective public health work, in the sense in which it is done in, say, the United States and England. He says (55, pp. 38 and 39): "I had noticed, indeed, that the natives felt a strong repugnance against going to our hospitals; so I conceived the idea, last year, of making medical tours into the parts of the country which are inhabited by natives alone.

"It seems to me that since the natives pay part of the expenses for public aid, it is legitimate and necessary to let them profit by it themselves.

"These tours were eminently successful. Of course the physician who only passes through cannot care for the cases of

chronic disease, but he can treat all other affections and relieve them, and that is doing a great deal. The people — particularly those of the *Aurès* — received with enthusiasm the physicians we sent them.

" Also, on one of the tours which I made in Algeria on the occasion of the last famine (which was more serious than M. Pauliat seems to think) I noted that in certain remote districts the natives were not afraid to go to the ambulance. On inquiring the reason for this I was told what it was. What the Arabs do not like in our hospitals is our administration, that is, the uniform rules which compel a patient, while he is in the hospital, no matter what may be the demands of his religion, his customs and his tasks, to eat the food prepared in the single hospital kitchen, and to undergo a sort of administrative regimentation which seems perfectly simple to us, but against which the native absolutely rebels.

" I thought, therefore, that in regions which are far away but in which the Arab or Kabyle population is very dense, one might establish special hospitals for this population. We are studying this question now. I am convinced that if we succeed in bestowing the benefits of public aid upon the natives they will be exceedingly grateful to us for them."

Piquet (100), writing in 1912, reviews in considerable detail what has been done in the way of public health and medical service by the French for the native population. In regard to the former the only thing he is able to point to is vaccination service and the ophthalmic service, which latter has consisted largely in distributing boric acid free to natives. There has also been sporadic distribution of quinine in the same way. He is sharply critical of the French administration in regard to what they have done, or rather failed to do, in the way of health service to the native population. The following remark

is illuminating in its implications (*loc. cit.* p. 255): "Les femmes avaient été négligées encore plus que les hommes, *si c'est possible*" [my italics].

At the present time the situation as to public hospitals in Algeria is as follows, except for such changes as may have occurred since December 31, 1921, the date of the latest available statistics (48, p. 44). There are 13 civil hospitals, 5 "Hôpitaux-hospices," and 3 hospices. These are staffed by 91 physicians, surgeons, and pharmacists, 171 "religieuses," and 671 employees and servants. These institutions provide 3971 beds for the sick, 1437 for the aged, infirm, and incurable, and 748 for the personnel of the institutions themselves. Unfortunately the official report makes no separation of the return as to hospital resources on the basis of race.

So far the discussion has been essentially of curative rather than preventive medicine. Great as the value of this service has undoubtedly been in recent times in relieving the suffering of the native population it cannot reasonably be supposed to have had any significant effect in lowering the general death rate of the population.

Turning to public health work, in the strict sense of the prevention of disease, there are fortunately available as sources of information an official document (47), and a book by Lavion (23) who was an official of the government, and therefore presumably writing more or less authoritatively. Since the two accounts agree in all essentials, and that of Lavion is in some respects more illuminating as to actual conditions, I shall quote from it rather than (47). Lavion says regarding public hygiene (pp. 40 and 41): "The question of hygiene showed itself later to be of great importance.

"The springs were covered over and numerous canalizations were made and kept up so as to supply the population of the region with healthy drinking water separate from that

meant for cattle, for which the number of troughs and ponds were increased in all the douars.

" In this connection I am reminded of a remark which was made to me many a time in the course of my wanderings among the native population.

" Old Mussulmans, not tolerating reforms and not understanding the need of drinking clear pure water, have sometimes said to me: 'We cannot make up our minds to drink the French water,' (meaning the clear limpid water flowing from the fountains constructed for their use by the French government). 'That water makes us sick and we prefer the Arabian water,' (meaning the dirty water taken from the 'oueds' or from springs not yet covered over).

" From the point of view of hygiene, France did not stop after this first reform. She was trying to clean up the country in which our subjects contracted malaria and attacks of pernicious fever. She set herself to ascertain the causes of this terrible disease which had been decimating the population. She assigned to famous physicians the mission of finding means which would be able to change this dreadful state of things. Swamps were filled in or covered with petroleum, and a quinine service and preventive measures against the fever were organized.

" The Arab physicians, — laymen with purely empirical methods, — were inadequate to the needs of the population, and a corps of physicians called 'colonial physicians' was organized to bring them medical aid.

" These faithful practitioners rendered great service and eradicated many epidemics of typhoid and smallpox. They were assigned monthly rounds to definite points in the different douars in order to bring to the natives, gratis, the benefits of their skill, as well as medicines.

" Vaccination rounds were also assigned to these doctors,

who at first had real difficulty in putting into practice the instruction of the administration, until the decree of May 27, 1907 made obligatory for Algeria the vaccination measures to which the diminution in smallpox epidemics is due."

This account of the situation needs to be compared with, in order to strike a fair balance, the following criticism from a native source (8, p. 17), which it should be said is mainly directed against the supposedly corrupting effect of the customs and habits of the French population, relative particularly to alcohol and prostitution, upon the indigenous native population: "I must call to your attention in passing a fact not very far removed from the question of customs which we are discussing, — namely, the fact that the material aspect of the life of the rural natives has not improved under domination. On the contrary these natives crowd closer and closer together in the rustic-looking tent or gourbi in sterile regions, abandoning the fertile fields in the selfish grasp of the invading colonist.

"What is there to be said for a domination of 85 years when most of these inhabitants are compelled, for example, to spend whole days traveling to regions far from colonists to get water because the sources of drinking-water which formerly supplied the douars are covered over and directed into subterranean conduits to supply the settlements occupied by cosmopolitan electors.

"And I am speaking not of Nomads, whom we are leaving to their habitual wanderings, but of sedentary groups of people who pay taxes and who are being condemned to drink the bad water of the oueds (contaminated streams) where the fever and other diseases cause a frightful mortality. But I will go no further, but will simply say that though the rural Mussulmans die in consequence of a lack of public hygiene which the government does not provide, at least they are not often

guilty of the ignoble sin of succumbing to the ravages of alcohol as are a goodly number of their co-religionists if they have dipped ever so slightly into the mixture we call French civilization."

Other evidence on the matter is furnished by Piquet (100) already cited. A voluminous treatise by Perier (105) on hygiene in Algeria, in the great series of *Explorations scientifiques de l'Algérie,* has to do with the hygienic conditions as they existed in the country early in the French occupation, and with hygienic advice to the French troops and colonists.

Jones and Dow (146) in speaking of the standard of living of the Algerian population say (p. 6): "It is estimated that of the 5,000,000 Mohammedans in Algeria and the south territories, only about 200,000 live up to minimum European standards."

Marchoux (161) has recently studied malaria in Algeria, particularly at Murengo, a place of about 7000 inhabitants partly colonists and partly natives. He states (p. 205) that malaria is very prevalent especially among the natives, almost all of whom are bearers of the parasites. In 64 examined 27 harbored at the moment great numbers of the parasites in their blood. Among 37 colonists (Europeans) examined at this place 16 had parasites in their blood. Judged by the criterion of enlarged spleen, samples of the population from two different places indicated a 60 per cent morbidity incidence of malaria. Certainly this does not indicate a very effective public health effort against this disease.

Before attempting to make a general evaluation of the evidence on the point under discussion, and the drawing of conclusions, it is desirable to consider another angle of the mortality and health of the native population of Algeria. I refer to the heavy infant mortality and its selective character. The best introductory statement regarding the matter is per-

haps that of Bertherand (50) who says (pp. 228–229): "Are the conditions surrounding the natives of Algeria favorable to the development of epidemic diseases? The answer to this question is certainly 'yes' if one notes that there general hygiene is almost nil; that they do nothing to avoid or remove the piles of vegetable and animal débris; that they are under-nourished, that their habitations are badly built and damp; that the earliness of their marriages and their venereal excesses have a profoundly debilitating influence, etc. The answer is certainly 'no' if one observes that they have no manufacturing industries; that their régime is simple and their life generally not very active; that existence in the open air and in small groups exempts the masses from the disadvantages and dangers of large and populous cities; that the sad state of public and private education does not, at least, precociously exhaust the intelligence of the young and does not hinder in any way the free development of the various organs, and, finally, that the religious dogmas of Mohammedanism impose upon the nervous system a placidity which has incontestibly a happy influence upon the etiology, course, and outcome of disease, etc. Finally (to terminate this rapid sketch of general conditions favorable and unfavorable to epidemics and, in consequence, to a temporary increase in the mortality rate) one must bear in mind the essential fact that all weak, delicate, non-robust individuals, or individuals violently attacked by serious accidents die very early, either through lack of proper care or through the permanence of the pathogenic causes themselves, and that, in consequence, the epidemics that later rage among a population whose robust elements have all been preserved, evidently meet with more energetic resistance to their ravages and appear, in other words, to cause a much lower mortality than that which would obtain among a people more advanced in civilization."

The same facts about the heavy and selective infant mortality have been observed and recorded by many others, indeed even by the most casual travellers. Thus Thomas-Stanford (33) writing more than a half century later than Bertherand says (p. 33): " A vigorous childhood ensures the survival of the fittest; the Arab children are left to themselves, naked in heat and cold, in sun and rain and frost, and only the hardiest reach manhood. The result is seen in the finely tempered physique of the race, in the Arab's extraordinary powers of enduring, and in his disregard of hardship and suffering. Whole tribes are infected with what is called the disease of civilization; typhus and smallpox sometimes blaze like a flame among them; the Arab scorns precaution or cure, and lives or dies with indifference."

Writing of the Arabs in Arabia Harrison (110) says (p. 30): " Most of his children die because of the unsuitable food, the hard condition of life and the ignorance of the parents."

The same selective mortality prevails among the Berbers of Kabylia. Discussing these people Wilkin (25) says (pp. 92–93): " The children were in a shocking state of filth and neglect. In the winter life must be very hard for the youngsters. Constantly soaked, with no better means of drying them than a smouldering fire whose smoke blackens everything before it finally discovers an exit, and the keen air of the mountains, they die at an early age of affections appropriate to such surroundings, all except the hardiest who live to be the parents of a new generation. In nature this is as it should be. In an artificial society like our own it is horrible, but it exists. . . . It is a pity that a happy mean cannot be found between rearing children obviously doomed to ill-health for life, and allowing all to die who are not quite strong enough to face a winter which, as often happens, is only exceptionally severe."

Even so casual a traveller as Shoemaker (58) does not miss this point. Speaking of Mohammedanism in Algeria he says (p. 217): "What is there in that religion to hold its people so? Is it lust, or indolence? Certainly from any decent standpoint there can be no recommendation found in it as it is today, — the degradation and enslavement of the women, the filth and disease in which the people live and will live forever, the awful mortality amongst the children with whom it is only the strongest that survive, — in little Biskra they die at the rate of several a day, — the absolute lack of advances or improvement of any sort, that is Islamism, that will be Islamism unto its final extinction."

The age distributions of the mortality of the native and the European populations of Algeria in the period 1911–1913 are shown in Appendix Table 16 and Figs. 20 and 21. The data are taken from Bunle (1). For comparison are added the life table death rates given by Glover (53) for the total population (white and colored) of the original Registration States of the United States in 1910, at the central year of the specified age periods of Appendix Table 16.

From Appendix Table 16 and Figs. 20 and 21 the following points may be noted:

Up to age 35 the specific death rates for the European population of the *Territoires du Nord* of Algeria are higher than those for the United States (original Registration States, total population including both white and colored). This difference may fairly be taken, I think, to denote the relative environmental superiority, in respect of matters of sanitation and public hygiene, of this country over Algeria at that time. Such a conclusion seems reasonable from every point of view. The only alternative explanation which suggests itself is that the American population is superior in innate biological soundness and stamina. Such an inference would seem to be highly

improbable, in the face of all the facts, certainly more improbable than the environmental explanation.

After about age 35 right away to the end of the life span the age specific death rates of the female European population

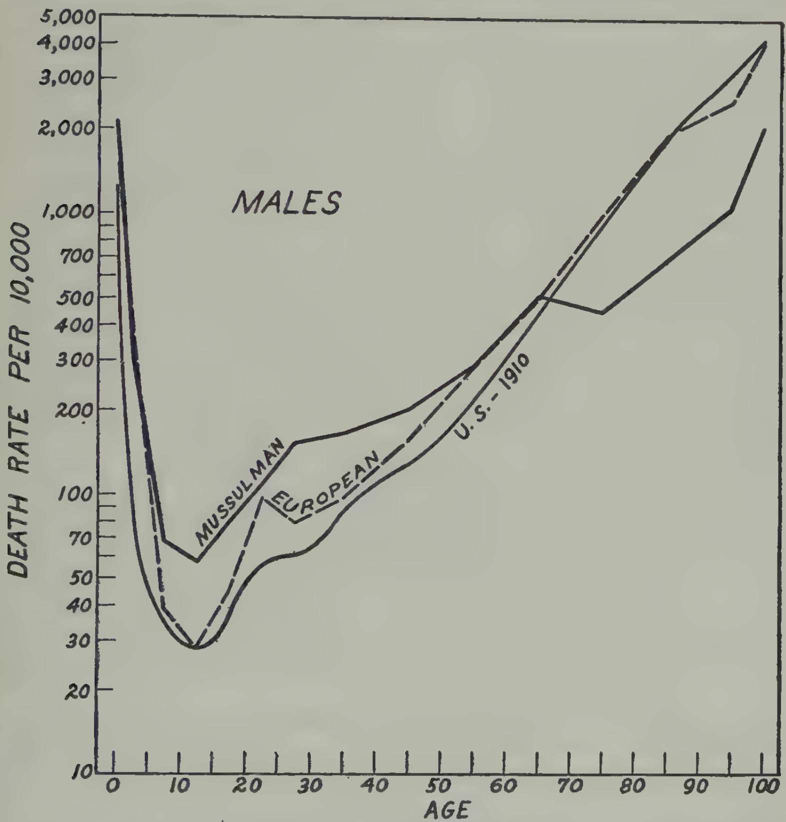

Fig. 20. Age specific death rates for males. (a) Mussulman in Algeria — solid line; (b) Europeans in Algeria — dash line; (c) United States, Original Registration States, 1910 — smooth curves.

in Algeria (Fig. 21) are obviously in no essential way different from the United States life table death rates for the general

female population, having regard for the errors incident to sampling. The two lines wind in and out about each other in a manner indicating substantial identity of course. In the

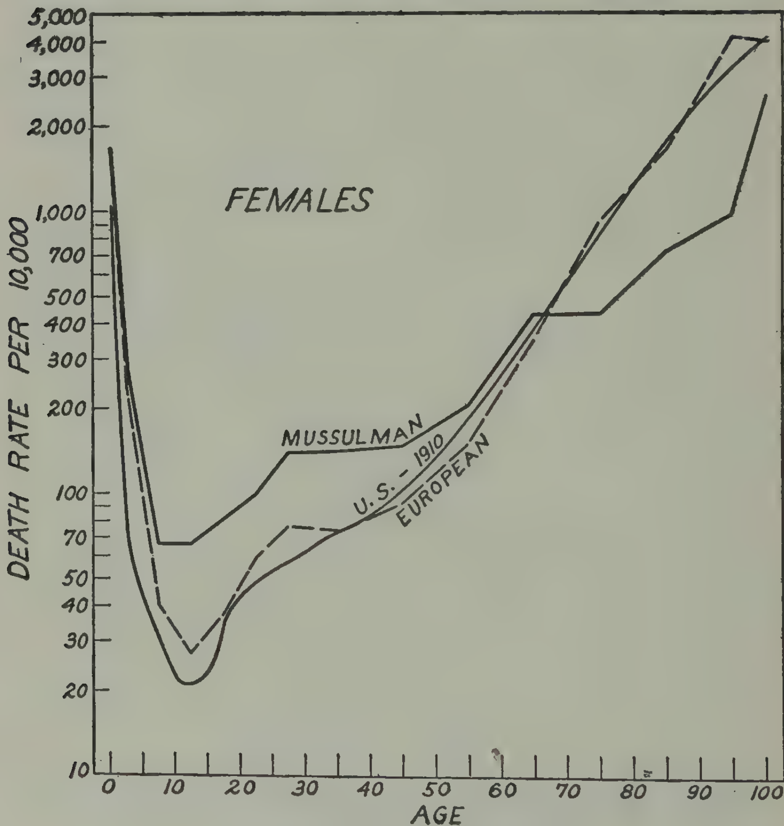

FIG. 21. Like Fig. 20, but females.

case of the males (Fig. 20) the European inhabitants of Algeria have higher age specific death rates than the United States population throughout life until age 85 is reached. After age 35 the differences are not great, but still they are

there. After age 85 age specific death rates are not highly exact or reliable in any case.

Apart from the difference already noted it is apparent that the general form of the age specific death rate curves for the European population of Algeria is closely similar to that of United States life table curves. Considering the fact that the Algerian data are entirely unsmoothed, the closeness of this shape similarity even in detail is really rather remarkable. It is, of course, in part explained by the fact that the Algerian rates are based upon an averaging of the observed mortality over several years. It indicates two things, I think: first, that the mortality relations of the European moiety of the Algerian population are essentially normal and regular; and, second, that the registration of death statistics in that country is on a sound basis and functions with the sort of accuracy that we expect in what are perhaps usually regarded as more advanced countries.

Turning to the Mussulman population of Algeria a widely different case presents itself in respect of the specific death rate curve. In both sexes the death rates at all ages up to 55 (with the single exception of males 1–4) are considerably higher than in the European moiety of the population. From 55 to 65 they are slightly higher in the Mussulman group, but practically the same as in the European. From age 65 on to the end of the life span the Mussulman population exhibits a mortality at ages not only markedly lower than that of the European population of Algeria, but lower than the life table death rates in the United States. The whole picture presented by the Mussulman curve is that of a population living under natural conditions in which the force of natural selection — the weeding out of the weak in the earlier periods of life and the survival of the strong to ripe old age — has full play.

Because the statements of age, both of the living and the

dead, are probably not as exact in the case of the Mussulman population as in the European, the Mussulman specific death rate curve is not so smooth as the European. The Mussulman rates at age 65 are probably too high and those at 75 too low in both male and female curves. In short, with more extensive and more precise data the two curves would probably cross at age 55 rather than 65.

Taking the unsmoothed data as they are, we have the system of percentage differences in the specific death rates between the European and Mussulman moieties of the Algerian population, shown in Fig. 22.

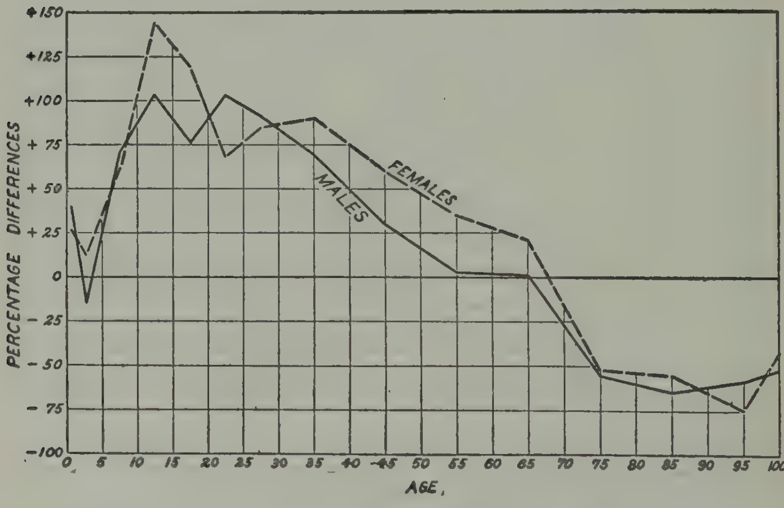

FIG. 22. The differences between European and Mussulman age specific death rates expressed as percentages of the rates for the European portion of the Algerian population. Solid line, males; dash line, females.

From the diagram it appears that the greatest percentage excess of the specific mortality rates of the Algerian native population over the European are in youth. Up to age 35 the native rates are, save in the period before age 5, on the

average from 60 to 80 per cent higher than the corresponding rates for the European population. From age 35 on the percentage excess of the native rates lessens steadily. After age 65 the native rates are roughly 25 to 60 per cent *lower* than the corresponding rates for the European population.

As bearing upon the selective character of the death rate and the superior vigor of the old, manifested in their lower specific death rates at advanced ages, the following statement of Naphegyi (96, p. 157) is of interest: "Among these people, the aged never become so dull and infirm as they do with us. Generally their bodily agility and freshness remains apparently unimpaired until within a few days before death, which seems to come upon them almost without warning."

Making full allowance for the element of error in the rates there would seem to be no doubt as to the general result that in the early part of the life span the age specific death rates are *higher* in the indigenous native population of Algeria than in the European population, and *lower* in the latter part of the life span.

Summarizing all the evidence presented in this and the preceding chapter I think we are justified in drawing two conclusions. The first is that up to the present time those environmental forces which may be generically called public health and sanitary measures, as these terms are understood in the countries of Western Europe and the United States, have had no significant effect in altering the natural course of mortality in the native population of Algeria. The weight of the evidence indicates that (a) no such measures in any widespread or effective way have ever been applied to the native population. The nearest approach to such effective application has been in the case of vaccination, but in recent years smallpox has not been at the worst a serious factor in mortality. Furthermore the internal evidence from the death

rates at ages indicates (b) that the mortality is of the form which would be expected in the absence of effective preventive medicine. Finally, all the ethnological evidence indicates (c) that the folkways of the native population of Algeria are such as to present the maximum of resistance to the application of European public health measures.

The second conclusion to be drawn is that in the absence of effective public health measures the death rate of the indigenous native population of Algeria has declined in recent years at a rate quite as rapid as that either of their European compatriots living in the same environment, or of the population of the most enlightened and progressive countries of the world in health matters.

The bearing of these results on the general problem of population growth will be discussed in a later chapter.

CHAPTER V

THE BIRTH RATE OF THE NATIVE POPULATION OF ALGERIA

THE birth registration in the *Territoires du Nord* of Algeria is on precisely the same footing as the registration of deaths, and probably nearly or quite as accurate. Appendix Table 17 gives the birth rate (live births per 10,000 inhabitants) in the *Territoires du Nord* for the 14 years 1901 to 1914 inclusive. In order to make clear the significance of the figures in this table, Fig. 23 has been prepared. This diagram plots the two columns of figures of Appendix Table 17 on an arith-log grid, again used in order that the slopes of the lines may with accuracy be visually compared.

It is evident at once that the birth rate is absolutely high for both moieties of this population; indeed, Bunle points out that it was higher in the period covered than that of any of the countries of Europe except the Balkan states, Russia, Hungary, Spain, and Italy.

There are two points of particular interest derivable from these figures. The mores of the European and the Mohammedan portions of the population are not more different in respect of sanitation and related matters than they are in respect of reproduction. It is a generally admitted fact that birth control by means of contraception is widely practiced in France. It is not necessary to detail evidence on this point. Not only do medical men discuss it (*cf.* for example Surmont (106)), but there is a great deal of propaganda literature of the type of (107) circulating in France at the present time.

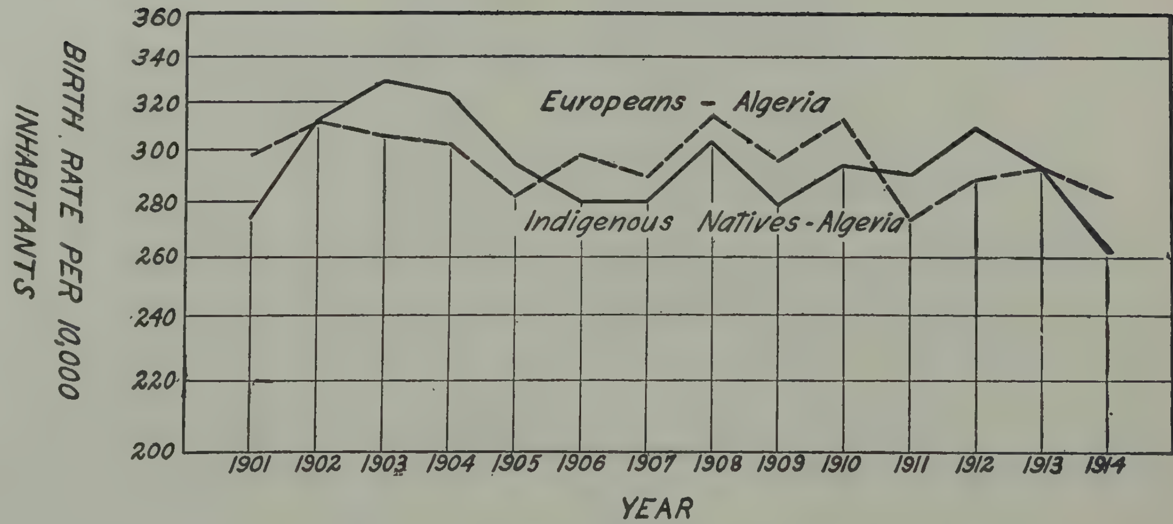

FIG. 23. The course of the birth rate per 10,000 population in the *Territoires du Nord* of Algeria, 1901–1914. European, dash line; natives, solid line.

The view is indeed widely held that conscious contraception is the chief cause for the present state of the French birth rate. There seems no particular reason to suppose that the French inhabitants of Algeria, who, as we have seen, comprise the great bulk of the European population of that country, behave in this respect differently than do their compatriots at home. Casserly (14, p. 55) says regarding the European population of Algeria: " Social life and customs are very much the same as in French provincial towns."

On the other hand, the Arabs and Berbers are notoriously much less concerned about the remote consequences of sexual activity than they are about its immediate pleasures. It seems entirely fair to suppose that birth control propaganda has, up to the present time, played an infinitesimally slight rôle in the home life of any Mohammedan people. Stopes (108, p. 252) is able to find " no explicit information concerning contraception in Mohammedan countries."

There are two outstanding features in the general picture which one gets from a study of the family life of the Arabs. The first is the excessive venereal appetite which characterizes the race, and the second is the low position of women in the social and family life, involving, as its concomitant, an utter lack of care for their feelings in any respect whatever. The first of these traits appears also to be shared by the Berbers, though in regard to the second they are racially somewhat superior to the Arabs. Both of these elements in the family life would seem clearly to preclude any systematic or extensive practice of contraception.

A little of the mass of evidence which exists in the literature on these points will bear quoting here. Lord Belhaven and Stenton (109, p. 590) in an article on the great Arabian leader Abd-el-Aziz Ibn Sa'ud records the following conversation, which is perfectly characteristic of the Arab male in general,

but takes on special significance from the fact that Ibn Sa'ud was admitted by every one (*cf.* Harrison (110) on this point) to be an unusually enlightened, kind, and high-minded Arab: " He was trying to set forth the respects in which Moslems are superior to Christians, and in some of these I must admit that he was right, though I, of course, stoutly maintained the contrary. Among these excellencies he instanced the practical absence of adultery among them, whereas it was such a commonplace matter among Christians that their very newspapers and novels were full of it. I said, 'Sheikh, we Christians' (Nasara, a word of contumely) 'are allowed but one woman to wife, even though we marry in extreme youth. How many have you had?' 'Four,' he answered, 'as the Prophet ordained.' 'Yes,' I said, 'I know that you have four at present, but how many have you divorced in the course of your life?' 'A hundred!' he roared with a hearty guffaw, which the whole audience took up in glee. I had not to elaborate my point, as those who know the Arabs will understand."

Casserly (14, p. 223) says: " The children from the earliest age are no strangers to any vice; for no attempt is made to conceal the knowledge of evil from them. For the Arabs are immoral to the core. Venereal disease is universal. To minister to their vicious desires old men purposely marry girls who have not yet reached the age of puberty. Married women are as unfaithful as the fear of their husband's wrath will let them be."

Douglas (6, p. 15) in speaking of the abject position of the women in Arab society says: " The wife owes obedience to her husband and must cohabit with him."

Gennep (20, p. 169) has the following to say regarding the status of women in the native population of Algeria: " They are married, sometimes from the age of eight on, to men between fourteen and sixty who exhaust them horribly. A

rather large proportion of young married women die from the consequences of the wedding night. Those who survive it are beasts of burden, even in Kabylia and among the Berbers. What is worse, the woman is not respected as a wife. She is consulted on the conduct of affairs if she is clever and practical, but this fact does not raise her in the esteem of her husband, her brothers, her sons, her male relatives, or men in general. Just because she is a woman she is kept in an inferior position, hardly above the animals, and far below the men."

Leger (46, pp. 43 and 44) quotes from *Souvenirs d'un chef de bureau arabe,* p. 117, as follows: "But it is in the private conduct of these women that I see their moral abjection. I do not wish to say anything about it here, but their libertinism is publicly notorious. The situation could hardly be different. The Arab woman has nothing but her senses and no one has taught her to resist their revolts. Reserve, decency, and modesty are virtues unknown to her. Her fidelity succumbs at the first favorable opportunity."

I shall next quote at length from two distinguished physicians, both of whom have devoted many years to an intimate study of Arabian life. They are both qualified by training and scientific interest to discuss the matter technically, and I feel justified in devoting so much space to the presentation of their conclusions because of the great theoretical importance of the point here at issue.

Bertherand (50) discusses various aspects of the sex life of the Arabs in the following terms (pp. 378–379, 381, 383–385, 389).

"Nous avons déjà parlé de l'onanisme: ajoutons que la fréquence des vers intestinaux est peut-être une cause prédisposante aux excès pernicieux de cette habitude, dont les effets se trouvent prévenus en partie par la précocité des mariages. Quant à la pression exercée sur le cervelet par les rebords du

calot souvent épais et endurcis par la crasse, pression qui, jointe au poids de toute la coiffure, s'exercerait particulièrement sur l'occiput et provoquerait ainsi la fréquence des érections, c'est une question difficile à résoudre. — 'Mariez-vous jeunes, disait *Mohammed,* la femme fuit la barbe blanche, comme la brebis le chacal.' Mais qu'entendre par le mot *jeunes?* Une tradition du Prophète, d'après M. Sale, traducteur du Koran, aurait fixé l'âge des unions sexuelles légales, ou de maturité nuptiale, à 15 ans; et *Abou-Hanefah,* un commentateur, pensait que 18 ans était le moment convenable. Combien alors nos Arabes sont loin de l'application de ces sages préceptes! Il faut avouer que le Prophète lui-même, en épousant la fille d'*Abou-Bekh* qui *n'avait pas encore* atteint sa *septième* année,[1] donna le premier le mauvais exemple, quoiqu'il eût soin de légitimer ses écarts de conduite par des révélations particulières de la divinité à titre de privilèges en sa faveur. Les Arabes de l'Algérie épousent souvent de jeunes filles *non réglées,* ou ayant de 8 à 9 ans à peine. 'Selon l'opinion générale, dit la loi musulmane, l'âge de copulation ou de nubilité est celui de *neuf ans;* avant cette époque, la conception est légalement impossible.' Ainsi la législation confond deux choses: l'apparition de la nubilité et le moment opportun de la copulation et de la gestation. Elle implique la nécessité, la convenance de ces actes coïncidemment avec les premiers signes du développement des organes aptes à les consommer.

" Il en résulte, comme Montesquieu l'observe fort bien, que les femmes 'nubiles à dix ans sont vieilles à vingt: quand la beauté demande l'empire, la raison la fait refuser; quand la raison pourrait l'obtenir, la beauté n'est plus. Il est donc très simple qu'un homme quitte sa femme pour en prendre une autre.' Les funestes conséquences de la précocité des unions

[1] Prideaux, *Vie de Mahomet,* p. 11 et 53.

sexuelles, surtout avant l'aptitude complète des organes génitaux et du corps à en supporter les fatigues sans danger pour la santé, ont été exposées plus haut avec assez de détails pour qu'il ne soit pas nécessaire d'y revenir.

"Les excès vénériens entraînent de grandes pertes nerveuses, moins graves au début pour l'Arabe dont le système nerveux est moins sensible, mais qui, trop souvent répétées, déterminent à la longue chez lui des spermatorrhées incurables, des affections organiques de la vessie et des reins. Les nombreuses maladies de l'appareil génital de la femme reconnaissent sans aucun doute pour cause principale la fréquence des rapprochements sexuels qui exalte si rapidement la sensibilité des organes de la reproduction. La misère qui sévit généralement sur la population ne pousse déjà que trop les Indigènes à chercher dans le coït leur unique distraction à des privations continuelles.

"Le rapide examen du texte de la loi, en ce qui concerne la médecine dans ses rapports avec les dispositions judiciaires, a fait également voir que toute copulation commencée doit être terminée, sous peine de péché. En effet, l'acte incomplet du coït fatigue bien davantage en empêchant l'accomplissement régulier, normal, de la fonction. Mais, d'un autre côté, cette sage recommandation de l'autorité religieuse n'aurait-elle pas eu pour but également de modérer la fréquence des rapprochements sexuels en favorisant, par la copulation complète, la naissance d'un plus grand nombre d'enfants? Evidemment, la multiplicité des naissances, dans ce dernier cas, doit engager les Arabes à mettre un frein à cette fureur charnelle, que M. Devay a si bien dépeinte par le nom d'onanisme conjugal. — 'Il vous est permis, a dit le Prophète, de vous procurer, avec de l'argent, des épouses que vous maintiendrez dans les bonnes mœurs et en évitant la débauche. . . . Ceux qui se maintiennent dans la chasteté et n'ont de commerce qu'avec

leurs femmes, seront dans les jardins du paradis. . . . Il vous est permis d'epouser les filles honnêtes des croyants; vivez chastement avec elles, ne commettez point de fornication, et ne les prenez point pour concubines, etc. . . .'[2] Outre ces exhortations à la chasteté conjugale, *Mohammed* s'est fortement élevé contre l'adultère: 'Si vos femmes commettent l'action infâme, appelez quatre témoins; si leurs témoignages se réunissent contre elles, enfermez-les dans des maisons jusqu'à ce que la mort les visite ou que Dieu leur procure un moyen de salut. . . . Evitez l'adultère, car c'est une turpitude et une mauvaise route. . . . Les femmes impudiques sont faites pour les hommes impudiques; les hommes impudiques sont faits pour les femmes impudiques. . . . Heureux sont les croyants qui évitent toute parole déshonnête, qui savent commander à leurs appétits charnels et qui bornent leur jouissance à leurs femmes; mais celui qui porte ses désirs au-delà est transgresseur. . . .'[3] Sous le gouvernement du dernier Dey d'Alger, c'est au cap Matifoux, près de cette dernière ville, que les femmes convaincues d'adultère, les filles publiques surprises en relation avec un Juif ou un Chrétien, étaient renfermées dans un sac et jetées à la mer par les agents du *mézouard* (chef de police).

"Les tristes conditions du mariage n'amènent que trop facilement de gros nuages dans les rapports des époux; les coups, les contusions sont le partage quotidien de jeunes femmes que le despotisme le plus barbare traite en esclaves dégradées. La loi, qui prévoyait bien cette douloureuse mais inévitable conséquence de la polygynie, a pris les dispositions suivantes: 'Lorsqu'une femme méconnaît ce qu'elle doit de respect, de soumission à son mari, le mari lui fera des exhortations et des

[2] Koran, ch. IV, v. 28; ch. LXX, v. 29; ch. V, v. 7.

[3] Id., ch. IV, v. 19; ch. XVII, v. 34; ch. XXIV, v. 26; ch. XXIII, v. 1, 3, 5, etc.

remontrances; quand il n'obtiendra pas d'amendement, il exclura cette femme du lit marital; à défaut de succès encore, il la battra, s'il pense que ce moyen violent puisse être utile et la ramener au bien. Les coups ne doivent produire ni fracture, ni blessure, ni contusion *sérieuse.*'[4] Tout commentaire devient inutile en présence de droits aussi violents, aussi injustes; on conçoit toute l'influence pernicieuse qu'ils doivent exercer sur la santé de la femme en particulier.

"La polygynie a le grave inconvénient d'amener une vieillesse précoce et un degré, plus ou moins complet, d'impuissance prématurée. Aussi les Indigènes fatiguent-ils les médecins français de demandes constantes de substances qui puissent réveiller l'énergie des organes générateurs. La loi musulmane indique elle-même le but de l'ablution avant le coït, à titre d'agent tonique et devant prévenir l'épuisement consécutif, d'autant plus sensible ou certain que l'acte est plus souvent répété. 'A défaut d'eau, la lustration pulvérale (sable ou terre) avant la copulation n'est point indiquée, car cette lustration n'a pas l'effet qu'on se propose par la lustration par l'eau, c'est-à-dire *qu'elle ne produit pas l'excitation convenable* pour le coït.'[5] Voilà donc clairement expliques, d'une part le but essentiel des ablutions qui à titre de tonique général tiennent tant de place dans la loi religieuse des Arabes, et de l'autre, l'effet bien positif de l'eau sur l'énergie des organes générateurs affaiblis par la polygamie.

"Le coït avec ou sans éjaculation séminale régulière est permis avec la femme qui allaite. Le Prophète a dit: 'J'eus l'intention de défendre le coït avec la femme pendant l'allaitement, jusqu'à ce que j'appris que les Grecs et les Perses pratiquent ce coït sans qu'il en résulte rien de nuisible pour leurs enfants.' Le Prophète jugeait dans sa pensée que ce

[4] *St Khelil; du Mariage,* ch. V, sect. 15e.
[5] *St Khelil; du Mariage,* chap. I, section 8e.

coït n'était pas exempt d'inconvénients pour le nourrison." [6] Et il n'avait point tort; mais nos Arabes sont d'un avis tout différent; et ce qui prouve bien qu'ils s'occupent fort peu de la double influence du rapprochement sexuel sur la grossesse et sur l'allaitement, c'est que les couches coup-sur-coup sont assez fréquentes chez les femmes indigènes. Du reste, les dérangements qui apparaissent si souvent dans la menstruation, dans la sécrétion laiteuse ou lochiale et deviennent le germe de beaucoup d'affections utérines, indiquent suffisamment combien la femme arabe néglige d'habitude tout ce qui concerne l'hygiène de ces diverses fonctions. Elles ont de bien singulières coutumes à ce sujet. Ainsi, dans les villes, quand elles ont leurs règles, elles vont au bain maure, et à la fin de la séance, elles s'ablutionnent vivement et copieusement les parties sexuelles avec de l'eau très froide; cette pratique aurait pour but d'activer l'écoulement menstruel. Les femmes des tribus connaissent également cette propriété des liquides froids."

More than a half century later another distinguished medical man, a graduate of the Johns Hopkins Medical School, Dr. Paul W. Harrison, has the following to say regarding the Arabs of Arabia (110, pp. 68–70): "To a new arrival from America the most surprising difference between the society he has left and the new society he now enters, is in the relation of the sexes. All animal appetites are strongly developed in the Arab, but nowhere has the development been so unbalanced and harmful as in the appetites and passions which are connected with sex. These appetites are perhaps as intensely developed in the Arab as in any race in the world. Certainly they are far more intense than in Europe and America. The Arab knows three pleasures, perfumes to smell, food to eat and women to enjoy. In ten years' medical work in Arabia, I

[6] *St Khelil*, t. III, chap. X, p. 129.

have yet to interview the first Arab in search of a tonic because his business cares or any other of life's ordinary activities were proving too much for his strength. Hundreds have come to ask for some elixir to prolong and increase the physical pleasures of parenthood. The customs that the Arab's appetite has created allow him four wives and as many concubines as he desires. He may divorce any wife at his pleasure and sell any concubine. Thus he may change partners at will and contract a new alliance at any time the fancy strikes him — whenever, in fact, he finds his first partners getting a trifle old or otherwise unattractive, quite commonly after they have borne children and have less to offer in the way of sex gratification. The result can be imagined. The pleasures licensed and endorsed by such a public opinion come to dominate the whole emotional horizon. Perhaps ninety per cent of the conscious enjoyment of the Arab comes to reside in this particular experience.

"We might expect to see especial care spent on children in such a country, and all life centering around them. If the forces of religion had been exerted to this end, perhaps that is what we should see, but as a matter of fact, religion has surrendered to custom and desire and the far easier path has been followed which leads to the focusing of all attention on physical sex indulgence, with children a mere necessary encumbrance. The world of the Arab does not revolve about the children. They are a mere incident, although they are petted and spoiled. What he delights in is the physical enjoyment of a new and pretty wife.

"Fortunately there are natural limits to this indulgence. The number of women in Arabia is not greatly in excess of the number of men, and obviously the percentage of men who can have four wives is a small one. Arabs universally have an abnormally developed sex appetite, and their whole emo-

tional life revolves around it, but not all have surrendered equally to this type of excess. Polygamy is almost unknown among the nomad Bedouins of the desert and divorce is uncommon. The poorer classes in the oases and in the coast towns share to some extent in the immunity of the Bedouin. None of them, however, show as fine a family life as his and for a very simple reason. They are not so poor, and the evil example of the rich is closer at hand to corrupt their minds and desires, even if because of their poverty it cannot corrupt their practices.

" Among the wealthy the system is carried out to its limits. Some of the oasis chiefs are among the worst offenders. I know one or two of them who are reputed to average a new wife every month. The merchants of the oases and the coast towns are nearly as bad. It goes without saying that only the rich and the great can indulge themselves to this extent, for it takes a great deal of money to change wives in such a fashion. However, it also goes without saying that any society whose ideals and religious teachings include and endorse a system such as this, and whose promised abode of future bliss is nothing but an exaggeration of the same thing, will show much the same moral tone all the way down to the very lowest strata."

Now, while the evidence is overwhelming, I think, that conscious contraception (birth control) plays no significant rôle in the determination of the birth rate of the indigenous native population of Algeria, still from Fig. 23 it clearly appears that while the crude birth rate of the European population has at times been higher than that of the indigenous native population of Algeria, *they both declined at substantially the same rate between 1901 and 1914.*

Whether one looks merely at the absolute position of the two lines, or whether one considers the problem of the world-wide decline of the birth rate as exemplified in this particular

instance of Algeria, he is likely to wonder about the relation of the practice of birth control to demographic statistics. In point of fact, Algerian figures which seem to me to come nearer to recording a large scale experiment than any others available (because it would be, so far as I know, difficult to find two sets of people more widely apart in regard to their prudence and foresight respecting the consequences of sexual activity than are the French and the Arabs) lend strong support to the view which has been advocated by Yule (111) regarding the declining birth rate.

It is a matter of considerable interest to compare the rates of decline of the birth rate in the two portions of the Algerian population with those found in other countries, just as in the preceding chapter the rates of decline of the death rates were similarly compared. To this end, Appendix Table 18 has been prepared which gives, from data compiled by Knibbs (131) (*cf.* Pearl (132) p. 164) the birth rates per 10,000 of the population for the years 1900–1913 inclusive, for the following countries: England and Wales, France, The Netherlands, Denmark.

As the simplest and most intelligible method of making these comparisons between slopes of the birth rate lines, the data of each column of Appendix Table 18 have been fitted by the method of least squares with a straight line. The equations of these lines are as follows:

England and Wales	$y = 297.40 - 4.14x$	(xxvi)
France	$y = 221.10 - 2.44x$	(xxvii)
Netherlands	$y = 327.95 - 3.60x$	(xxviii)
Denmark	$y = 301.68 - 2.65x$	(xxix)
Algeria, native population	$y = 306.68 - 1.65x$	(xxx)
Algeria, European population	$y = 305.46 - 1.26x$	(xxxi)

The fitted slope lines are shown graphically plotted on arith-log paper in Fig. 24.

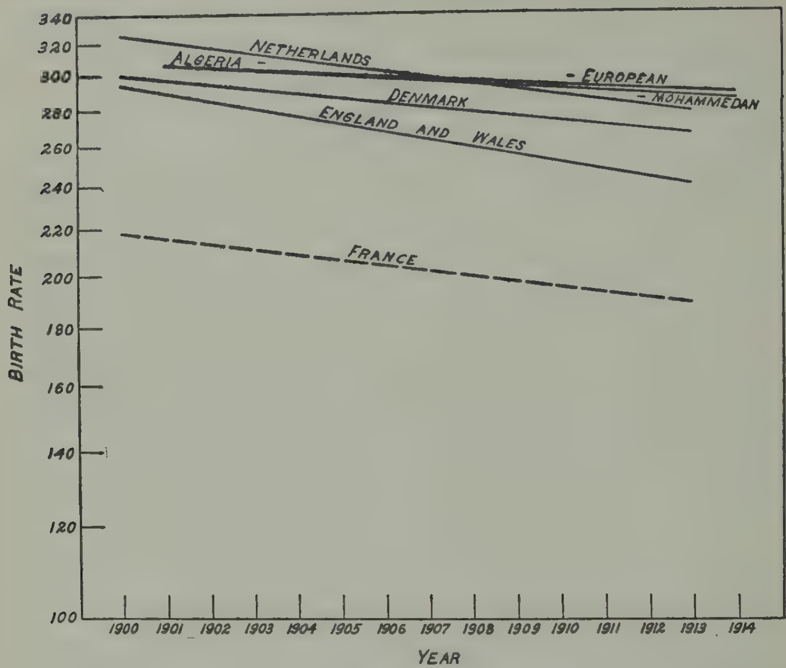

FIG. 24. The trends of the birth rates per 10,000 population in various countries, as indicated by the fitted straight lines.

Proceeding as in Chapter IV we have for the relative slope indices the following:

	Slope Index 100 b/a
England and Wales	-1.39
France	-1.10
Netherlands	-1.10
Denmark	-0.88
Algeria: European population	-0.41
Algeria: Mohammedan population	-0.54

It is thus seen that the decline of the birth rate of the native population of Algeria has been slightly more rapid than has that of the European population in the same environment.

The birth rate of both moieties of the Algerian population has declined less rapidly than has that of any of the European countries compared. This slower rate of decline of the birth rate in this period is precisely what would be expected from the theory of the logistic curve, considering the position of each of the populations compared on their own logistic, and their death rates, as Yule has shown (see discussion in later portion of this chapter). It is of interest to note in passing that the birth rate in Holland, where birth control clinics are officially recognized, declined no more rapidly than did that of France, where birth control was opposed officially and by propaganda in this period, and less rapidly than did that of England and Wales.

The decline of the birth rate in the absence of the practice of conscious contraception is well known in various primitive races. Thus Hadfield (112, p. 182) says of the natives of the Loyalty Islands: "A marked feature of the present day is the serious fall in the birth rate in native families of every class. This is certainly not due to any Malthusian practice. It is, as has been intimated elsewhere, a source of grief and humiliation to the married couples. Twenty or thirty years ago one rarely met a childless wife, but now they are to be found in scores in every district of the island."

Smith and Dale (113) note the same thing among the Ila-speaking natives of Central Africa. They say (Vol. I, pp. 15 and 16): "The natives who inhabit the country . . . number some sixty thousand, the female sex predominating in the proportion of three to two. When the advantages under which the Ba-Ila live — their numerous herds, the abundance of fish, the frequent windfalls of meat, and their productive soil — when these advantages, comprising all an African desires, are remembered, it will be a matter for surprise that their numbers are so small, (p. 16)." "One reason, perhaps

the chief, is the unproductiveness caused by the astonishing promiscuity of their sexual relations and the extreme earliness of age at which these relations commence. It is no exaggeration to state that from the age of seven or eight a girl, married or otherwise, counts her lovers, who are constantly changing, not singly but by the score. The writers at the time of the first census of the people were amazed to find kraal after kraal inhabited solely by adults, and to receive time and again the same reply that there were no children, that, much as they wished for them, conception was a very difficult matter."

It seems doubtful if Smith and Dale's explanation of the declining birth rate as due to excessive venery can be true in this case, for there is no reason to suppose that the habits of the people in this regard have undergone any recent secular change, and the change in the birth rate would seem to demand, on their theory, a change in habits.

Another example of the same sort is to be found in Rivers' (114) well-known study of the depopulation going on in Melanesia generally.

The wide-spread prevalence of endemic syphilis of very mild clinical manifestations among the native population of Algeria will not help, I think, to solve the problem presented by Figs. 23 and 24. The reason is that, so far as I have been able to find, there has been no *alteration* in the situation regarding syphilis in the last 25 years, and however much it may be thought to have to do with the absolute value of the native birth rate, it can scarcely be regarded as a causal factor to explain the same rate of decline of the native birth rate as that of the European birth rate during the 14 years under review. In fact, the high absolute value of the indigenous native birth rate as compared with that of European countries indicates that the influence of syphilis upon the reproductive rate must have spent its force many years ago.

The close association between precocious marriage and low fertility was brought out in a convincing manner many years ago by Rouvier (144) in his statistical study of 1400 gynecological cases in the Beirut Hospital. In the whole material there were 79 cases of very early marriage. These he divided into four groups. The first of these consisted of 11 women who were true *nulliparae,* that is had not only not borne any children, but had not even been pregnant. Five of these first menstruated at an average age of two years *after* marriage. The whole group of 11 averaged 29 years of age after 15 years of marriage.

The second group consisted of 29 women each of whom had had term deliveries only, that is, no abortions or miscarriages. Eight of these had their first menstruation 10 months after marriage, and averaged 28 years of age after 16 years of marriage. These 8 had borne 31 children, or an average of 3.9 each. Eight other women in this second group had married under 15 years of age (exact age at first menstruation unknown) and at the end of 14.5 years of married life had produced 21 children, an average of 2.6 each. The remaining 13 in the group married after puberty, having first menstruated on average of 1.67 years before marriage. At the end of 13.5 years of married life they had borne 48 children, or 3.7 each.

The third group included 32 women who had both term births and abortions. In 9 of these menstruation first began at 1.25 years *after* marriage. At the end of 21 years there had been 51 pregnancies of which 21 resulted in abortion, leaving 30 term births or 3.3 per mother. Seven women in the third group were married at about the time of puberty. After 21 years of married life there had been 44 pregnancies, with 11 abortions, leaving 33 term births or 4.7 per mother. Finally in this third group there were 18 women who had married at

an average period one year after the onset of menstruation. At the end of 18 years there had been 111 pregnancies with 33 abortions, leaving 78 term births or an average of 4.3 per mother.

The fourth or final group included 7 women all married under the age of 14, and at the end of 12 years had had only 11 pregnancies, all ending in abortion.

Grouping the whole series together on the basis solely of time of marriage in relation to puberty gives the following results:

No. of cases	Average time of marriage	Average duration of marriage to observation	No. of preg-nancies	No. of abor-tions	Average per mother of	
					Pregnan-cies	Term births
23	20 months before first menstruating....	16 years	83	22	3.6	2.6
16	At puberty..	18 years	65	12	4.1	3.3
40	18 months after first menstruation....	17 years	168	42	4.2	3.15

Rouvier concluded that extremely early marriage diminished fertility and increased the frequency of subsequent abortions. The latter conclusion seems less definitely supported by the statistics here quoted than the former but is probably justified if we consider the whole group of 79 placed against normal women. He also showed that there was a marked increase in uterine disease.

Holder (145) in his interesting discussion of the sex life of American Indians mentions (p. 44) excessive venery as one of the factors concerned in the production of abnormally low birth rates among these people.

It is probable that early marriage and excessive venery are

important factors in keeping the birth rate of the Mussulman portion of the Algerian population at the absolute level where it is, a level not greatly different from that of the European portion of the population. But, as has been pointed out above, these cannot reasonably be adduced as causes of the *decline* in the birth rate, because there is no reason to suppose that there is going on any *change* in the habits of the people in these respects in the direction which would be required to fit such a theory.

The essential similarity of the two portions of the Algerian population in regard to fertility may be shown in another way.

TABLE VII

LIVING BIRTHS PER 10,000 WOMEN OF EACH SPECIFIED AGE. (TERRITOIRES DU NORD — MEAN OF YEARS 1911–1913)

Group	Under 20 years	20–24 years	25–29 years	30–39 years	40–49 years	50–59 years	60 years and over	All ages
Mohammedan ...	299	1433	2153	1553	482	64	6	1041
European........	271	1623	2289	1389	251	11	4	862

This Table VII, which gives the age specific fertility rate of women in the two principal racial groups of the population, is shown graphically in Fig. 25, for the ages from 20 on.

From age 30 on the age specific natality rate is higher among the native women than among the French. It is lower in the age groups between 20 and 30, but nowhere are the differences very considerable. The alleged birth rates beyond age 50 are, of course, to be regarded with suspicion, although Bertherand (50) says that by Mussulman custom a woman is not officially presumed to be incapable of child-bearing until the age of 60 is passed. Davis (133, p. 22) states that in 1921 in the United States Birth Registration Area 9 mothers were originally stated to belong in the age period " 55 and

over," but upon investigation to verify the statements no one of the 9 was found to be as old as 55.

In order to check in some degree the Algerian specific fertility rates of Table VII I have calculated the corresponding

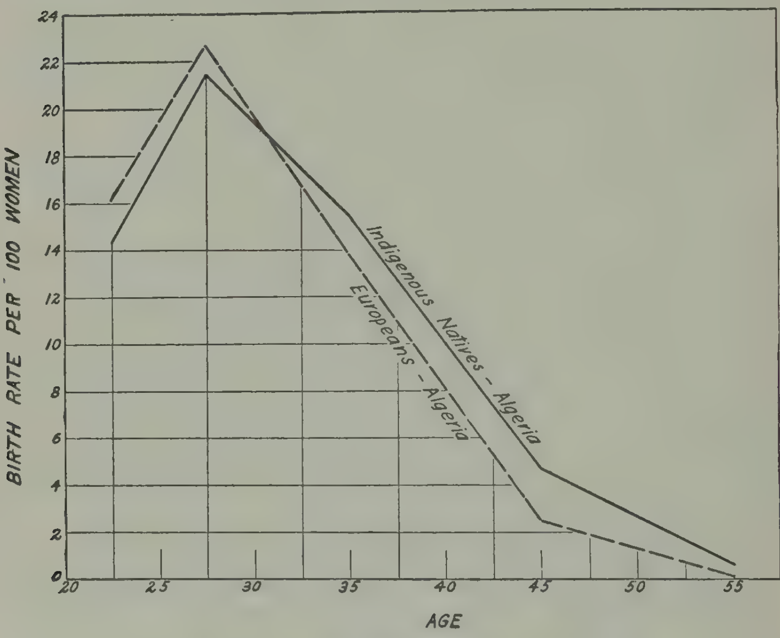

FIG. 25. Age specific fertility rates of women from age 20 on in the *Territoires du Nord* of Algeria. Solid line — natives; dash line — Europeans.

figures for the states of (a) New York and (b) Utah, for the year 1920. Utah has a high birth rate, and has predominantly a rural population. New York contains the largest city in the country, and in general is farther away from pioneering conditions. It is impossible to get the rates for precisely the same age groupings as those of Table VII, but they are near enough to serve the present purpose.

TABLE VIII

LIVING BIRTHS PER 10,000 WOMEN OF EACH SPECIFIED AGE. NEW YORK STATE AND UTAH, 1920

State	15–19 years	20–24 years	25–34 years	35–44 years	45–54 years
New York.........	276	1247	1256	474	12
Utah..............	396	1785	1885	1004	44

It is evident that the age specific fertility rates, calculated per 10,000 of the total female population, show a closely similar distribution in the case of the population of Utah to what is shown in Table VII to be the case in the native Mohammedan population of Algeria. This fact is particularly well brought out if one plots the rates on a diagram like that shown in Fig. 25. This result is of interest as indicating that a considerable degree of reliance can be placed in the Algerian statistics. The New York rates are much lower, as would be expected, but still have a generically similar form of distribution.

Before going further it will be desirable to examine in *résumé* our progress to this point. It has been shown in what has preceded that populations of living things, from the simplest, represented by yeast, to the highest, represented by man, grow in accordance with the logistic curve. The native Algerian population discussed in Chapter III affords a crucial case. It is a human population which has virtually completed a cycle of growth according to the logistic curve within the period of recorded census history. One can now feel more certain that this curve is a first and tolerably close approximation to a real *law* of growth for human populations, than was possible when the completion of a cycle for a human population demanded extrapolation of the curve for many

years beyond the period of the observations, as in the cases of human population growth depicted in Chapter I.

The problem which must now be attacked, and to the discussion of which the remainder of the book will be devoted, is this: what are the factors which determine that the curve of population growth, the stretched-out S-shaped logistic curve, shall have the curious form that it does? Here lies the real problem. So far both our task and our accomplishment have equally been descriptive. It has been shown *how* populations of yeast, flies, and men grow, and that they all grow in essentially the same kind of way. But *why* do they grow in this particular and peculiar way rather than in some other?

In general terms it is perfectly easy to answer this question. The form of the population growth curve, in the case of a population unaffected by migration, plainly must be determined by the changes in the course primarily of the birth rates, and secondarily of the death rates, for that population. In short it is the form of the birth and death rate curves which determines the form of the logistic curve for a population, and not *vice versa*.

Yule (86) has dealt particularly with this point from its theoretical aspect, and Netusil (115), working recently in my laboratory, has discussed it briefly for the particular case of the population of Bohemia. Yule's discussion of the theory of the matter is so important that I shall quote it in full. He says (pp. 37–38): "Suppose our population to have existed for a long time under one set of conditions — *e.g.*, the conditions of an agricultural population — to have passed through its cycle and to have stabilized down, so as to have reached the age-distribution (the life-table age-distribution) determined by the given death-rates at ages. Now suppose it to be suddenly jerked into a fresh cycle of growth, *e.g.*, by the advent of industry, by passing through an 'industrial revolution.'

I suppose this occurrence to happen at the time — 4 on the new cycle; the populations, death-rates and birth-rates are calculated as before, and Fig. 26 shows the results.

"The first consequence of the sudden fresh start in growth is to send *up* the death-rate very considerably above the life-table value (20.6), owing to the greatly increased numbers of infants and children at the younger ages, when mortality is high. As these increased numbers spread to the ages at which mortality is low, the death-rate rapidly drops until it reaches a minimum slightly under 15.5 between — 3.0 and — 2.8. As the increased numbers reach the more advanced ages there is a rapid rise to a temporary maximum of over 16.8 at — 2.2, then a drop to a minimum again about — 1.9, after which the death-rate steadily and continuously rises. After the epoch — 0.5, in fact, the death-rates in the present case are sensibly identical, to the second place of decimals, with those found in the first case: the effects of the temporary shock due to the sudden transfer to the new cycle have died away.

"The birth-rate curve shows the effects of the initial shock in a very similar way; it rises abruptly, and then falls with a marked wave, coincident with that in the death-rate, but settles down into the normal movement for the cycle before zero time, the centre of the cycle is reached.

"This second case represents, of course, an impossible abruptness of transition from stability to the cyclical movement, but as a limiting case it is, I think, illuminating. The effect of the impossibly violent shock is merely to produce an initial oscillatory movement in the death-rate, which completely expires in a period of 150 to 175 years in a population increasing a little more rapidly than our own. The effect on the birth-rate is similar. Thereafter, the normal cyclical movement of the death-rate and the birth-rate is resumed. In fact, of course, the birth-rate might fail to react with the

rapidity suggested by Fig. 26, and the more probable consequence might be fluctuating divergences from the logistic.

"It may be concluded that in any case the normal movement of the death-rate during the cycle is a *rise throughout;* . . . but if the transition to the new cycle has been abrupt there may be irregularities — oscillatory movements — more or less like those shown by the lower curve of Fig. 26, but probably much less violent. But this normal cyclical rise in the death-rate would hardly in any practical case become conspicuous until after that point had been passed. The first is pretty much our own case, the second that of France: we are just beginning to appreciate the check to the fall in the death-rate due to changing age-distribution; France is feeling it heavily.

"Similarly, the normal movement of the birth-rate is *a fall throughout the cycle,* very slow at first, then rapid, but the rate of fall slackening rapidly as the second half of the cycle is reached: abrupt transition to the cycle merely introduces more or less violent oscillations in the early stages.

"The curves of these figures are ideal, calculated on the assumption that the death-rates at all ages are constant throughout the whole of the cycle. No country has in fact experienced so simple a state of affairs, for the death-rates at ages have in most countries been more or less rapidly falling — though by no means equally at all ages. The broad consequence of this fall would be to give the curves of Fig. 26 a downward tilt from left to right, making the birth-rate fall rapidly and the death-rate rise less rapidly, or even fall."

The theoretical case which Yule postulates in this discussion is essentially like that which we have observed in the indigenous native population of Algeria, as set forth in Chapter III. A population which presumably had for a long time been stable at its upper asymptote, was started off on a new logistic

cycle. And we have seen in the present chapter that in 14 years towards the end of the cycle the birth rate, *known to be essentially uninfluenced by the intentional practice of contraceptive measures,* has fallen just as Yule points out that it theoretically should.

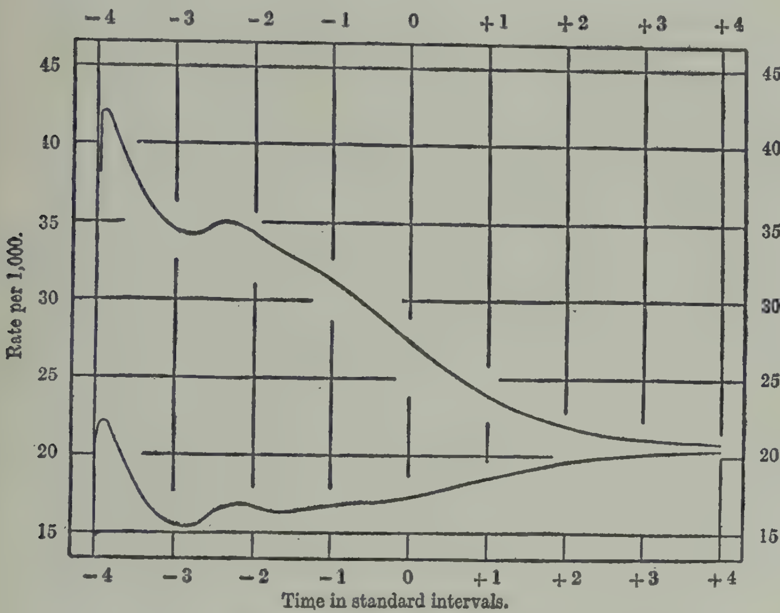

FIG. 26. The course of the death rate (lower curve) in a logistic population in which the death rates at ages are constant, when the population, after having attained the stable state, is suddenly jerked onto the logistic at epoch —4. (From Yule.)

Now while all these statistical relations hang very prettily together, the biologist is not satisfied to stop with this so beautiful concordance of theory and practice. It interests him to go further and try to find out why the birth rate falls. What are some of the underlying biological factors causing this?

The remaining chapters of this book will be devoted to the

discussion of this problem, not with the thought of completely solving it, but rather with the view of putting upon the record some new and pertinent bits of evidence regarding it. This evidence will be helpful for future work upon the matter, even though it does not finally settle the question at this time. It also has a certain methodological significance, as indicating in a general way where, in my judgment, emphasis needs to be placed in future studies of the population problem if they are to be really penetrating and fruitful.

CHAPTER VI

THE INFLUENCE OF DENSITY OF POPULATION ON FERTILITY

I

As a first point of attack upon the problem stated at the end of the last chapter it is desirable to return to the fruit fly *Drosophila* and consider the results of certain pertinent experiments carried out on that form in my laboratory. Just as in earlier chapters it will be found that the evidence got from an analytical study of the lower animal, capable of exact experimental control, gives useful suggestions and some light upon the problems presented by the more elusive, because uncontrollable, human material.

It has long been known that the degree of crowding of organisms in a given space, or density of the population, has an influence upon various vital processes of the individuals composing the population. In the matter of growth of the individual animal Semper (116) long ago showed that volume of water apart from food and other conditions has an influence upon the rate. This subject has again been studied recently by Bilski (117). Farr (118, 119) maintained that there is in human populations under certain conditions a definite relation between density of population and the death rate. This old work of Farr's has recently been taken up again and confirmed by Brownlee (120–122) for certain portions of the population of England and Wales. LeBlanc (125), working in my laboratory, has criticised incisively Farr's original work on the matter, and has further shown that for the population of

the United States, whether rural or urban, Farr's law does not hold. LeBlanc's conclusion, however, is that this failure of the American population to die according to Farr's law, does not in the least controvert or even really conflict with the results of experimental observations on lower organisms, where a definite and precise effect of density upon mortality has been demonstrated by Pearl and Parker (136, 137. *Cf.* also 138). The chief difficulty, as LeBlanc points out, is to get a *biologically* significant measure of density in human populations. It is not clear that persons per square mile is such a measure under the conditions of modern urban civilization. Drzwina and Bohn (123, 124) show that a particular concentration of a toxic substance, just lethal for a single individual in a given volume of water (working with such organisms as infusoria, planarians, hydra, tadpoles, etc.), will be sub-lethal if several individuals are present in the same fixed volume of water.

Without undertaking at this time any systematic review of the literature on this subject it is the purpose of this chapter to present some experimental and statistical data on the influence of density of population upon a different biological function than those mentioned above; namely that function which may be called the specific reproductive rate or fertility of matings. This variable we define relative to the first of the experimental studies to be reported, as measured by the number of adults (imagoes) of *Drosophila* produced per mated female per day over a specified period of time. Interest in this problem arose originally from purely practical considerations in the routine laboratory work. Anyone doing experimental work with *Drosophila* has constantly arising this situation: he wishes to start an experiment with a large number of flies of homogeneous make-up as a group. What is the most expeditious way to get the desired numbers while still maintaining the requirement of homogeneity? Is it better to mate a consider-

able number of pairs in one bottle to furnish the desired progeny, and if so, how many pairs? Or is it better to mate up one or two pairs only in each of several bottles? Which plan will give the largest progeny group? Not being able to answer this practically important question satisfactorily, either by *a priori* reasoning or by perusal of the *Drosophila* literature, it was decided to test it experimentally. The results proved to have a considerably wider interest than that implied in the purely practical question.

II

Mass matings were made on March 21, 1921 of flies from our line 107, the characteristics of which have been described by Pearl and Parker (126). When the offspring from the matings emerged they were used to make up the matings of this experiment, according to the following plan. Half-pint milk bottles were used, and the food arrangements, etc., were according to the standard *Drosophila* technique of this laboratory already described. The composition of the matings was as follows:

Series	No. of bottles	Mated pairs in each bottle at start	Series	No. of bottles	Mated pairs in each bottle at start
1	4	1	9	4	9
2	4	2	10	3	10
3	4	3	11	3	12
4	4	4	12	3	15
5	4	5	13	3	20
6	4	6	14	1	25
7	4	7	15	3	30
8	4	8	16	2	50

These bottles were put into an electric incubator kept at a constant temperature of 25° C. At the end of 8 days the parent flies still surviving were transferred to fresh half-pint

bottles and allowed to continue breeding for a second period of 8 days.

All the progeny flies as they emerged as adults (imagoes) from the two series of bottles were counted and recorded as to sex. No account was kept of larvae or pupae. We are dealing here with net reproductive capacity, just as in certain of our poultry work (Pearl 127). Food and temperature conditions were constant for all bottles throughout the experiment. The only significant variable between the several series was the density of population. There occurred various accidents to some of the bottles in the course of the experiment. Some of the mated flies died; food occasionally rose in the bottles and killed a few individuals, etc. In reducing the results to a per female day basis allowance has been made for these accidents, and the final results set forth below represent the outcome for normal mated flies living under normal laboratory conditions.

Inasmuch as only 16 days' progeny was counted the results cannot be directly stated in terms of total reproductive capacity. Instead they have been tabulated as the rate of reproduction per female day over a 16 day period after emergence. It is quite certain, however, that the absolute number of offspring per female in the first 16 days of life is highly correlated with the unknown total reproductive capacity. This seems sure from many observations on *Drosophila* and from analogous observations on fecundity and fertility in the domestic fowl.

III

The results of the experiments are exhibited in Table IX, and graphically in Fig. 27. The table contains the following data: (a) the numbers of mated *pairs* per bottle at the start. The numbers of mated *flies* per bottle were therefore

twice these figures at the start; (b) the mean population of mated flies over the whole period of 16 days. If no accidents had occurred these figures would have been 2, 4, 6, 8, 10, 12, 14, 16, etc. But accidents and deaths did occur. The figures set down represent the actual average number of flies present in each bottle over the period of the experiments, taken as a whole. (c) The mean number of flies per cubic centimeter of free air space in the bottle. Since all the bottles were by careful measurement of the food made to contain the same volume of free air space (130 c.c.) it follows that the entries in this column are simply a constant (1/130) times the entries in the preceding column. They are inserted merely to show what the actual density in these experiments was. (d) The mean number of flies per square centimeter of banana-agar, growing yeast on its surface, in each bottle. The same remarks apply to this as to the cubic density figure. It corresponds formally to the density of population figures of persons per acre or per square mile used in human vital statistics. The food area per bottle was 23.76 square centimeters. (e) The total female days, meaning the number got by adding together for all females the number of days that each was in the experiment. Thus if a female lived throughout the experiment she contributed 16 female days (1×16) to the total; if she lived 7 days she contributed 7 female days (1×7) and so on. (f) Total absolute number of adults (imagoes) produced in 16 days. These absolute figures vary of course with the accidental circumstances affecting the mated population. (g) The observed rate of reproduction, given as number of offspring adults (imagoes) per mated female per day. (h) The theoretical rate of reproduction (number of imagoes per mated female per day) as calculated from equation (xxxii) below.

TABLE IX

Experimental Data on the Influence of Density of Population on Rate of Reproduction

Pairs per bottle at start	Mean population average 16 days	Mean flies per cm^3 of space	Mean flies per cm^2 of food area	Total female days	Total imagoes in 16 days	Imagoes per mated female per day	y from equation (xxxii)
1	2.00	.015	.084	63	1348	21.4	21.1
2	3.40	.026	.143	89	1124	12.6	14.5
3	5.50	.042	.231	173.5	1877	10.8	10.2
4	7.32	.056	.308	232	2100	9.1	8.1
5	9.29	.071	.391	267	1585	5.9	6.7
6	10.29	.079	.433	298.5	2034	6.8	6.2
7	11.51	.089	.484	377.5	1951	5.2	5.6
8	14.48	.111	.609	436.5	1996	4.6	4.6
9	16.62	.128	.700	519	2117	4.1	4.0
10	18.74	.144	.789	275	855	3.1	3.6
12	21.70	.167	.913	504	1746	3.5	3.1
15	26.02	.200	1.095	609.5	1389	2.3	2.5
20	34.02	.262	1.432	754	1666	2.2	1.8
25	47.75	.367	2.010	384	388	1.0	1.1
30	47.73	.367	2.009	1069.5	1272	1.2	1.1
50	90.66	.697	3.816	1446.5	474	.33	.34

It is at once apparent from this table that there is a profound and regular change in the rate of reproduction of *Drosophila*, under the conditions of these experiments, with increasing density of population. The rate of reproduction per mated female per day declines as density of population increases, at first extremely rapidly and then more and more slowly at higher densities. The total number of progeny flies (23,922) is great enough to give confidence in the results.

A better appreciation may be obtained of the nature and regularity of this change if we put the results in graphic form. This is done in Fig. 27.

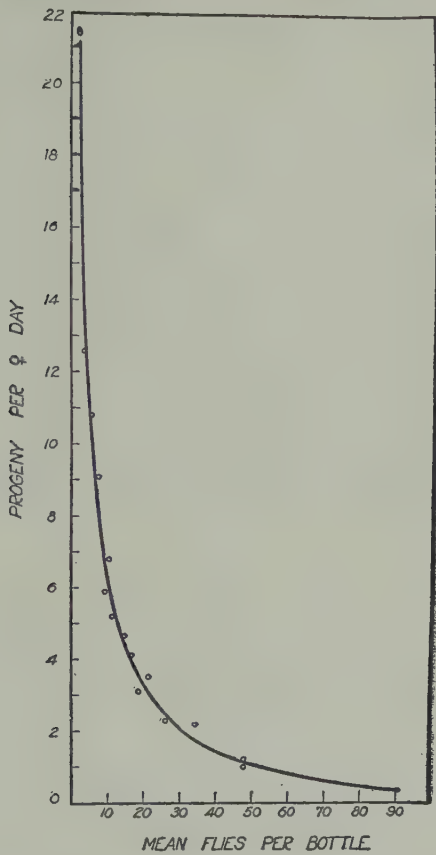

FIG. 27. Showing changes in rate of reproduction of *Drosophila* with increasing density of the mated population. The circles give the observations and the smooth curve is the graph of the logarithmic equation discussed in the text.

The smooth curve passing through the circles is the graph of equation (xxxii) fitted to the observations by the method of least squares. In this equation y denotes imagoes per mated female per day, and x denotes mean density of the mated

population (measured as flies per bottle) over the whole 16 day period.

$$y = 34.53\, e^{-.018x} x^{-.658} \qquad \text{(xxxii)}$$

Or, in logarithmic form,

$$\log y = 1.54 - .008\, x - .658 \log x \qquad \text{(xxxiii)}$$

It is at once apparent that this equation describes the observed facts with extraordinary precision. Rarely, even in a physical or chemical experiment, does one get such close agreement as is here shown between observation and theory. Plainly the curve is the expression of the law relating these two phenomena, rate of reproduction and density of population.

It is of interest to note that this equation is essentially identical in form with Farr's law relating death rate to population. Farr's original equation was the following, put in logarithmic form:

$$\log D = \log a + k \log d \qquad \text{(xxxiv)}$$

where D denotes death rate and d density of population and a and k are constants. Brownlee has slightly modified the constants but the essential form remains the same. Now in equation (xxxiii) the term in x is obviously of no practical importance, and could be left out entirely without greatly affecting the fit. It was only put in in a spirit of meticulous curve-fitting accuracy. With this term out, equation (xxxiii) becomes in form identical with Farr's (xxxiv) except that we have shifted the origin. The only essential difference is that in his case death rate is shown to vary directly with density of population, while in the present case rate of reproduction varies inversely with density, but according to the same law. Death and reproduction are both fundamental and antithetical biological phenomena.

What we know about the matter suggests that density of population has a profound effect upon many if not all general

and fundamental biological processes. Brownlee points out that the same law holds in racing for the relationship between the record time for any definite length of course and the length itself, and for other biological and biochemical phenomena. Bilski (*loc. cit.*) uses essentially the same equation to describe the influence of density of population on growth in tadpoles. Certainly the subject deserves further study. Possibly the present results offer a clue to a part at least of the solution of the problem of the nearly world-wide decline in the birth-rate which has been going on for a long time. One must be cautious, however, in applying unreservedly biological results obtained under relatively simple conditions, to human populations living in an extremely complicated environment, social, economic, and political, as well as physical and biological. We shall return to this point later on.

IV

How can the effect of density upon the rate of reproduction of *Drosophila* be explained? The extreme closeness of the observations to the theoretical curve indicates clearly that we are dealing here with no haphazard performance, but with a highly lawful phenomenon. The first point that occurs to one is that since we are dealing with adult flies (imagoes) only, the result may perhaps be explained by larval and pupal elimination due to overcrowding of the population in those stages. In the bottles say with 20 females there were laid, on this view, something like 20 times as many eggs as in the bottle containing one female, these eggs developed into 20 times as many larvae, there was not room or food for so many larvae, therefore many of them were selectively eliminated, and the number of survivors which got through to the imago stage indicated only a low reproduction rate, which repre-

sented, however, really only the capacity of 80 c.c. of banana-agar or 23.76 cm.² of food surface to nourish larvae, and nothing else.

Plausible as this hypothesis is — the more so because it would at once indicate why our rate of reproduction variable follows Farr's law, since it would then really mean Farr's law applying to the larvae — it cannot possibly account for the facts. To demonstrate this we have only to examine with some care the absolute figures given in the fifth column of Table IX. In the first place let it be recalled that the greatest drop in rate of reproduction (imagoes per female per day) occurs as we pass from a mean density of 2 flies per bottle to one of 3.4 flies per bottle (1 and 2 pairs originally). The next greatest drop in the rate is from the bottles of density 3.40 to those of density 5.50. Now at all these low densities one in fact cannot possibly speak of larval crowding at all. This anyone knows who has experimentally bred *Drosophila*. A half-pint bottle with 80 c.c. of banana-agar will support many more than all the larvae one or two or three females will produce in 8 days. This is indicated by the absolute figures in the fifth column of Table IX. The bottles containing 9 mated pairs at the start produced 2117 offspring imagoes. Therefore the food was sufficient to allow at least that many larvae to come through successfully. But in the bottles with one, two, or three mated females the absolute number of larvae was much less than this. Now the drop from the one pair to the two pair bottles in rate of reproduction was 8.8. To prove that this cannot be explained by larval crowding and elimination we have only to multiply 21.4, the rate per female day in the one pair bottles, by 89, the number of female days in the two pair bottles. This will give the number of imagoes which would have been produced in the two pair bottles had the reproductive rate of the one pair bottles held

there. The result is 1904.6. *But this is 200 or more less than the absolute number produced in various other bottles.* Therefore the drop in the rate from the one pair to the two pair bottles cannot be explained on the supposition of larval crowding and elimination. Possibly this factor comes into play in the higher densities, though there is no evidence as yet that such is the fact.

V

That density of population influences fecundity in the same sense that it is here shown to affect the rate of reproduction was demonstrated with fowls more than a decade ago (128). In the course of the investigations on egg production in the domestic fowl carried out at the Maine Agricultural Experiment Station a long-continued and elaborate series of experiments on the relation of crowding to fecundity were made. The birds in the experiment were handled in flocks of 50, 100, and 150 each. The pens in which they were kept were so constructed that in the flocks of 50 and 100 birds each there was an allotment of 4.8 square feet of floor space per bird, while in the flocks of 150 birds there was an allotment of 3.2 square feet of floor space per bird. The data accumulated in this experiment obviously furnish evidence, then, on two different questions. In the first place, we have data on the influence of the number of birds associated together in one pen on the egg production when the floor space per bird is the same. Evidence of this sort one can, of course, get by comparing the egg records for 50-bird pens and 100-bird pens. In addition there are data on the further question of the influence of amount of floor space *per se* on the egg production when one brings into the comparison the 150-bird pens.

In conducting this experiment on the influence of floor space on egg production great care was exercised to make constant

all conditions other than housing. The birds used in the experiment were all of the same breed (Barred Plymouth Rock) and furthermore were of substantially similar breeding within the strain. They were in every case birds bred from mothers laying between 160 and 199 eggs in a year, and from fathers whose mothers and earlier ancestors in the female line were birds laying 200 or more eggs in the first laying year. Furthermore, in sorting the birds into the various pens in the fall of each year over which the experiments continued great care was taken to make a *pro rata* distribution of the pullets of different qualities into the different pens. Thus, for example, the pullets on the range would be examined and the very best of them selected, then this selected group would be allocated in the proper proportions to the different pens in the experiment. The 100-bird pens would receive twice as many of this class of birds as did the 50-bird pens and the 150-bird pens three times as many. Then the second choice would be made of the pullets on the range, and these again divided among the houses in the same proportional manner. This procedure assured as even a distribution of birds in the several components of the experiment as probably could in any way be obtained.

Let us examine the influence of the factors size of flock and amount of floor space per bird on the mean or average annual egg production per bird. The data on this matter are presented in Table X. In addition to the actual means of the different pens for each year there is also given in the last column of this table the excess in the number of eggs produced per bird in the 50-bird pens over that in the 150-bird pens. The data in Table X are shown graphically in Fig. 28.

It is obvious that the mean annual egg production is markedly affected by differences in the environmental factors with which we are here dealing. In each year there is a decided

TABLE X

RELATION OF SIZE OF FLOCK AND FLOOR SPACE TO MEAN ANNUAL EGG PRODUCTION

Year	Mean annual egg production			Excess of 50 over 150-bird pens
	50-bird pens	100-bird pens	150-bird pens	
1904–5	134.60 ± 1.98	133.61 ± 3.47	114.54 ± 3.02	20.06 ± 3.61
1905–6	140.31 ± 1.81	127.50 ± 2.03	119.43 ± 1.54	20.88 ± 2.38
1906–7	114.16 ± 1.74	108.53 ± 1.92	101.08 ± 1.64	13.08 ± 2.39
Mean	129.69	123.21	111.68	18.01

difference in the average production of the different pens. Further, it is clear that the general trend of the annual averages is downward as the number of birds in the pen increases. In every instance the mean for the 100-bird pens is smaller than that for the 50-bird pens of the same year, and the mean for the 150-bird pens is again smaller in every case than is that for the 100-bird pens.

The decrease in the mean annual production as we pass from the 50-bird pens to the 100-bird pens is, in round numbers, taking the average figures for the whole three years, about 6 eggs. The difference between these two populations is not altogether regular from year to year. In the year 1904–5 it is so small as to be insignificant in comparison with its probable error. In 1905–6 the difference is relatively large, amounting to approximately a dozen eggs. In 1906–7 it is about the average, namely 6 eggs. These results, it will be observed, are perfectly consistent in their general trend throughout the whole course of the experiment, and there appears to be but one conclusion possible. That conclusion is that with the general plan of feeding and housing followed in the experiment, even though the amount of floor space per

individual bird remains the same, the average egg production per bird in a year's laying is distinctly and significantly smaller when the birds are in flocks of 100 than it is when they are in flocks of 50 birds each. The larger the crowd the smaller the egg production, even though the number of birds per unit area, or the unit area per bird, is the same in both crowds.

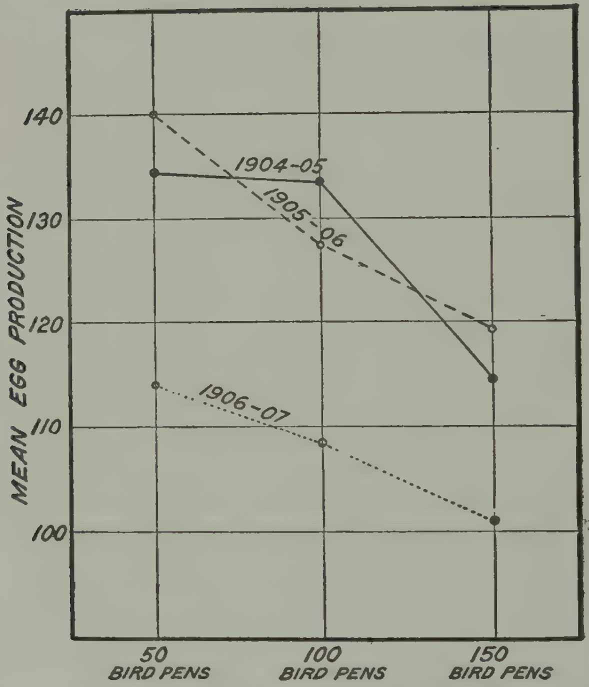

FIG. 28. Mean annual production with different amounts of floor space per bird.

The differences between the averages for 100-bird pens and 150-bird pens are, on the whole, distinctly larger than those between the 50-bird and the 100-bird pens. Taking average figures, the mean annual production is approximately a dozen

eggs smaller in the 150-bird pens than it is in the 100-bird pens. As in the other case the absolute amount of the decrease varies in different years, although the general trend is entirely consistent throughout the course of the experiment. From these results it seems reasonable to conclude that under the conditions of the experiment, when we have the combined influence of an increase of number of birds in the flock together with a decrease in the amount of floor space per bird, there is a notable decrease in the average annual egg production.

If we consider the maximum difference due to the influence of different amounts of floor space and flock size, as shown between 50- and 150-bird pens, it is seen to be large in amount and relatively constant in different years. In round numbers, the birds in the 50-bird pens averaged to lay a dozen and a half eggs more per bird per year than did those in the 150-bird pens.

The experiments seem rather clearly to indicate that with fowls there is another element apparently involved in the case besides mere physical density of population, which element in our ignorance we may perhaps tentatively call psychological. Apparently there is an effect upon the physiological processes of reproduction resulting from the keeping of large numbers of individuals together in a confined area or space, even though the amount of space or area *per individual* is identically the same in the larger crowds of individuals as in the small crowds.

In general there can be no question that this whole matter of influence of density of population, in all senses, upon biological phenomena, deserves a great deal more investigation than it has had. The indications all are that it is one of the most significant elements in the biological, as distinguished from the physical, environment of organisms.

VI

What now of human populations? Does a relation of the same sort that has been shown to hold for *Drosophila* and the domestic fowl manifest itself between density of population and birth rate amongst human beings? This is a much more difficult problem to solve than those just dealt with. In the first place the experimental method of attack is excluded in the nature of the case. We cannot set up a series of controlled universes as we can with flies and hens. This throws the method of attack upon the problem over into the statistical realm. The statistical method is rarely ever as satisfactory as the experimental, for a variety of reasons, of which one of the important practical ones is that it is usually found that just the precise statistics needed to give a fairly crucial picture of the situation of interest have never been collected, and therefore are not of record.

Furthermore, in the present case, the problem is made more difficult by a considerable uncertainty as to what is a biologically *significant* measure of density in the case of human populations. In the case of the flies and the hens the area or volume, or both, of the container have an obvious and simple relation to the amount of food available to the population and to the amount of energy which the individuals composing the population must spend in food getting. But in an urban population of human beings " persons per acre " has no such direct and simple relation to the biological fundamentals of living. Higher density, as so defined, may in a human population well bespeak greater ease, not difficulty, in getting an adequate food supply, by virtue of the operation of certain simple and fundamental economic factors in distribution. Persons in the most densely crowded parts of cities can get an adequate supply of vitamines from green vegetables during the

winter months, for example, much more easily and cheaply than can the rural dweller. The jobber can profitably ship spinach in January from the southern states to large cities, because the aggregate distribution will permit large lot shipments, but he cannot possibly afford to send this product to the small rural villages of Maine or New Hampshire at that season. The price would necessarily have to be so high that no one would buy.

LeBlanc (125) in his study of the relation of mortality to density says (p. 555): " Human beings, with the exception of those confined in prisons and like institutions, are never subjected to the continual pressure of population density that may be obtained in an experiment. An individual may be housed at night under conditions of excessive crowding, while two thirds of his time is spent in an outdoor occupation, with no crowding. Conversely an individual living in the sparsely settled suburbs with plenty of living space at his disposal, may be exposed to markedly congested conditions during the day. The development of present day urban life has reached a stage where scores of families live on a single plot of ground, and yet one family is scarcely conscious of the presence of the others. As long as the conditions of population do not make themselves apparent to the individuals involved, it is not probable that they affect the biology of those individuals."

It is probable, I think, that the appropriate conclusion to be drawn from such considerations as those just adduced is not that density of population does not affect biological processes in human beings, but rather that persons per square mile or per acre is not biologically so significant a measure in the case of human beings as the equivalent constant is for lower animals under experimental conditions. It will be worth while to see, even with the imperfect tools available,

what can be learned about the relation of human birth rates to density of population.

To this end the investigation now to be reported has been carried out. The method used has been that of partial correlation. The reader not familiar with this development of biometric technique should consult the accounts of it in Yule (147) or Pearl (132). Here it must suffice to say that if

$$r_{xy} = \frac{S(xy)}{N\sigma_x\sigma_y} \qquad \text{(xxxv)}$$

be taken to express the correlation of zero-order between two variables X and Y, having deviations from their respective means of x and y, with standard deviations σ_x and σ_y, then the higher order correlations involving 1, 2, 3 . . . n additional variables will be given by the expression.

$$r_{12\cdot 3\,\ldots\ldots n} = \frac{r_{12.34\cdot\ldots\cdot(n-1)} - r_{1n.34\cdot\ldots\cdot(n-1)}\cdot r_{2n.34\cdot\ldots(n-1)}}{(1 - r^2_{1n.34\cdot\ldots\cdot(n-1)})^{\frac{1}{2}}(1 - r^2_{2n.34\cdot\ldots\cdot(n-1)})^{\frac{1}{2}}}. \qquad \text{(xxxvi)}$$

What the constant $r_{12\cdot 345}$ measures is the *net* correlation between the two variables designated by the subscripts 1 and 2 respectively, when the three other variables designated respectively by the subscripts 3, 4 and 5, are held constant, and any effect from them upon the variation of 1 and 2 therefore eliminated.

In the present study interest centers upon the *net* correlation which exists between birth rate on the one hand, and density of population, as measured by persons per acre, on the other hand, after the influence of certain other factors has been eliminated. These other variables which it seems most important to hold constant, for reasons which will appear as we proceed, and the subscript notation for all variables studied are as follows:

B = Births per 1000 married women, 15–44 years of age.
A = Persons per acre.

$P =$ Total population.

$W =$ Per capita wealth of the population.

$S =$ Per cent of population aged 18–20 attending school.

$D =$ Persons per dwelling.

The following statements will show the precise limitations in space, time, and content of the statistical data used, and also the sources from which they were taken. Since all the original data are matters of record in official United States public documents it seems unnecessary to go to the expense of printing in this book the zero-order correlation tables used in this study. In correlating birth rate with density all cities in the United States Birth Registration Area with a population of 25,000 or over by the 1920 Census for which data for all factors were available were used, except that cities having 10 per cent or more of their population colored were excluded. This was done to remove the influence on the correlation of the most important item of racial heterogeneity in the United States. The number of married women of 15–44 years was taken for each city from Tables 16 and 17 (pp. 463–572) of Chap. IV, Vol. II of the 14th Census, 1920. Births for 1920 are from Table I (pp. 48–57) of Birth Statistics, 1920. Births per 1000 married women aged 15–44 were calculated from these data. There are thus two small sources of error in the rates, neither of which is of practical importance: (1) number of married women is that enumerated at the beginning of the calendar year, (2) births include both legitimate and illegitimate. However illegitimate births form only 2.1 per cent of total births in all cities of the registration area, and will be still less important when cities with large colored populations are excluded. Population and persons to a dwelling for each city were taken from Tables 3 and 4 (pp. 1268–1270) of Chap. XIV, Vol. II of the 14th Census.

The per capita wealth of the various cities is the estimated

true value of the per capita assessment subject to the general property tax from Table 30 (pp. 318–351) of Financial Statistics of Cities, 1919. This involves omitting some cities under 30,000 in 1919 but over 30,000 in 1920. However it seems to be the least of evils between which there is opportunity for choice.

Per cent of persons 18 to 20 years of age attending school is from Table XII, Appendix B, School Attendance in the United States, 1920 Census Monograph V.

Persons per acre was obtained by dividing populations estimated as of middle of fiscal year by land area (acres), both from Table 1, Financial Statistics of Cities, 1919.

VII

We may turn now to a consideration of the results. There was found first the gross, zero-order correlation between birth rate per 1000 married women 15–44 years of age, and persons per acre in the 132 cities included in the study. The list of cities, and the value of each of the variables for each city, are given in Appendix Table 19.

The zero-order gross correlation between birth rate and density is

$$r_{BA} = -\ .037 \pm .059 \qquad \text{(xxxvii)}$$

Obviously this coefficient depicts an absence of significant correlation between these two variables in their raw state. The coefficient departs from zero in the negative direction by an amount less than its probable error.

But the influence of other factors correlated with birth rate, or with density, or with both, may be masking in this gross zero-order coefficient a real organic correlation between the two variables. Thus it occurs to one at once that a correction

should be made for absolute size of total population of the cities, for two reasons. The first is that there is an element of so-called "spurious" correlation in the coefficient r_{BA} because both B and A are ratios involving, in part, common factors. Thus

$$B = \frac{1000 \text{ Births}}{\text{Number of married women aged 15–44 in the total population}} \qquad \text{(xxxviii)}$$

and

$$A = \frac{\text{Total population}}{\text{Acres of land area}} \qquad \text{(xxxix)}$$

Furthermore there is a sensible correlation between size of city as measured by total population and at least one of the two variables B and A. The correlations are:

$$\left.\begin{aligned} r_{BP} &= -.043 \pm .059 \\ r_{AP} &= +.307 \pm .053 \end{aligned}\right\} \qquad \text{(xl)}$$

The first of these is insignificant, but the second is by no means so. The larger the total population in these cities the higher the density (persons per acre).

So then the next step is to determine by the application of equation (xxxvi) the net correlation between birth rate and density as defined, when the total population is held constant and its influence on the results thereby eliminated. Doing this we get:

$$r_{BA\cdot P} = -.025 \pm .059 \qquad \text{(xli)}$$

This result, which is sensibly equal to zero, indicates that variation in total population of these cities has very little effect upon this correlation between birth rate and density of population. But there are other variables which may play a more important rôle in the matter. For example it is known (see next chapter) that birth rate and per capita wealth of a population are negatively correlated to a sensible degree.

What will be the effect of this factor upon the correlation between birth rate and density? It is difficult to get really accurate and significant data on per capita wealth. About the best one can hope to do is to get some figure which will serve fairly as an index of the unknown true per capita wealth. In this study there has been taken as such an index the estimated *true value* of the real property subject to general property assessment. The following zero-order correlations are found:

$$\left.\begin{aligned} r_{BW} &= -.381 \pm .050 \\ r_{AW} &= -.061 \pm .059 \end{aligned}\right\} \qquad \text{(xlii)}$$

The first of these is significant, the coefficient being more than 7 times the probable error. In this group of cities the greater the per capita wealth as here defined, the lower the birth rate. Somewhat unexpectedly there is found to be no significant correlation between density of population (number of persons per acre) and per capita wealth. The explanation is probably to be found in a certain balancing of economic factors in the case. While the working people in an industrial city tend to make for high density and low per capita wealth as here measured, they also, on the other hand, tend to make it possible for there to be resident in the same population a considerable number at least of persons of high per capita wealth and plenty of land area surrounding their dwellings. The two tendencies seem to balance each other rather effectively in the correlation.

The first order correlation of birth rate and density, with per capita wealth constant is

$$r_{BA \cdot W} = -.065 \pm .058 \qquad \text{(xliii)}$$

and if we pass to the second order coefficient holding *both* population and per capita wealth constant we get

$$r_{BA \cdot PW} = -.075 \pm .058. \qquad \text{(xliv)}$$

This result begins to look encouraging. It indicates that taken together total population and per capita wealth did have a small influence in masking the correlation between birth rate and density.

A factor which on general grounds one would expect to have an important influence on human birth rates is the general intelligence of the population. Evidence will be presented in later chapters showing the importance of psychological factors in relation to sex habits. General experience indicates that in the less intelligent strata of human society less forethought is exercised in regard to the having of children than among the more intelligent. Clearly there is need to introduce into the partial correlation nexus which we are developing some variable which will be in some degree indicative of the general level of intelligence of the population. After some thought the percentage of children aged 18–20 attending school has been chosen for such an index. It is obviously not a perfect measure of the thing we are trying to get at. But no perfect measure is available in official statistics. The percentage of children 18–20 attending school is in some sense a statistical ratio opposite in its implications to percentage of illiteracy. The age group 18–20 is above the age of *compulsory* school attendance and will therefore indicate the extent to which the people of a given city desire, in the aggregate, to give their children something more than the minimum of required education. The children at these ages will be in high schools, technical schools, or colleges and universities.

The zero-order correlation between birth rate and this school attendance 18–20 variable shows at once that the reasoning just stated was substantially correct. We find

$$r_{BS} = -.351 \pm .051 \qquad \text{(xlv)}$$

Also there is a sensible correlation between this variable and density, the value being

$$r_{AS} = -.229 \pm .056 \qquad \text{(xlvi)}$$

What these coefficients mean is that the greater the percentage of school attendance between 18 and 20, the lower the birth rate, and the lower the density (persons per acre) in this group of cities. This is precisely the result which would be expected on general grounds.

Putting this variable S into the net correlation scheme leads to the following value:

$$r_{BA \cdot PWS} = -.131 \pm .058 \qquad \text{(xlvii)}$$

This coefficient means that when total population, per capita wealth, and percentage of advanced school attendance are all held constant together, the net correlation between birth rate and density as measured by persons per acre is negative in direction (*i.e.*, the greater the density the lower the birth rate) and in magnitude is now more than twice its probable error. It becomes increasingly evident that the original supposition was true that the insignificantly small zero-order coefficient between birth rate and density in these 132 cities was the result of a masking of the true correlation through the influence of other variables.

It has been suggested that housing density (persons per dwelling) is biologically a more significant measure of density in human populations than is persons per acre of the total area of the city. It will presently appear that this supposition is probably, indeed almost certainly, not true. But it is desirable to determine just what will be the effect of holding this variable constant in the partial correlation nexus. Doing this we find.

$$r_{BA \cdot PWSD} = -.175 \pm .057 \qquad \text{(xlviii)}$$

It thus appears that if total population, per capita wealth, percentage of school attendance 18–20, and persons per house are made constant for these 132 cities, the net correlation existing between birth rate and density of population is negative in sign and slightly more than 3 times its probable error. This result indicates that in these urban human populations *the real net correlation between birth rate and density is of the same character fundamentally as that we have found in experimental populations of flies and hens.* As perhaps might reasonably be expected the influence of density upon birth rate seems to be less marked in human populations than in those of lower animals. This I take to be merely an expression of the fact that human life is in many ways far more complex than that of lower animals.

There is a curious paradox which has come to light in this partial correlation study. Suppose that instead of taking persons per acre as the measure of density to correlate as the primary variable with birth rate, persons per dwelling be used in this position. The resulting fourth order correlation coefficient is

$$r_{BD \cdot PWSA} = +.456 \pm .046 \tag{xlix}$$

This result would seem on its face to indicate a totally opposite relation of density and birth rate to that found in the experiments on lower animals, and in human populations when persons per acre is used. But I believe that this would be an incorrect inference. There was in 1919 and 1920 generally a housing shortage in the cities with which we are here dealing and a slackening in new building operations because of high prices. A careful study of all the data indicates that, in those years at least, birth rate was having a direct positive effect upon housing density, in the following sense. Given a limited number of houses in a city, all in the nature of the

case, that is in the nature of houses, inexpansible; then add to the population by births. The result is bound to be that as the birth rate varies in the positive direction, the number and the size of dwellings remaining much more nearly constant, the ratio of persons per house will increase, that is vary in the positive direction also. This will lead at once to a positive correlation between birth rate and housing density, as a result not of the effect of housing density upon rate of reproduction, but as a mere mechanical consequence of putting more new babies into a lot of containers comparatively inflexible in respect of both number and size. The study of this somewhat paradoxical situation has convinced me that housing density can be regarded as a biologically significant measure of human population density under such conditions as obtain in American urban communities, only when there is available to the whole population a surplus of dwelling houses, so that any family wanting to live in one by itself will have both the physical and the economic possibility of doing so. Even then it is doubtful if persons per dwelling would be really as significant a measure of population density as is the "persons per acre" constant.

The conclusion that human fertility is negatively correlated with density of population was reached many years ago by Brownell (150) from a study of the statistics of the several states. This work was done in the days before the modern theory of correlation was known to any but a few economic and social statisticians, and Miss Brownell's technique would be regarded now as crude, but the general conclusion appears to have been correct.

In this connection the discussion of the subject by Weber (151) in the pre-correlational period may still be read with some profit, though it is in no way conclusive.

VIII

The bearing of the results set forth in this chapter on the general problem of the causes lying back of the logistic curve is evident. As any population confined within definite spatial limit goes up on the logistic curve its density automatically becomes greater and greater. But if, as the evidence indicates, increasing density has associated with it the biological effect of a reduction in the rate of reproduction of the population exhibiting it, then obviously there is in this relationship a factor which may act as a *vera causa* in damping the time rate of growth in the upper half of the logistic curve. It would appear not to be the sole cause of this slowing off of the growth as the upper limit is approached, for the data of Chapter II show that there is no fixed or absolute relation, even under experimental conditions, between absolute density and the progress of the logistic. The whole subject obviously wants more investigation, but the definite evidence brought forward in this chapter of an association between the density of a population and its rate of reproduction is significant, and suggestive of new lines of research for the future.

CHAPTER VII

THE DIFFERENTIAL BIRTH RATE AND THE POPULATION PROBLEM[1]

I

EVERYONE who has thought seriously of the social implications of either the eugenics or the birth control movements has been puzzled and disturbed by the phenomenon of differential birth rates. If he has thought at all correctly about the matter he has perceived that in this phenomenon lies perhaps one of the greatest existing obstacles blocking the way to the fairly speedy attainment of at least some part of that earthly millenium which both these modern gospels so glowingly depict. The " wrong " kind of people have too many children, and the " right " kind too few. It almost seems as though some perverse dæmon possessed human kind, and made poor mortal fools do exactly the opposite of what a really enlightened self interest would indicate to be the right thing.

Thus recent figures on the relative fertility of different occupations in England and Wales show that the number of children per 100 married couples, when the age of the occupied husband is below 55 years are as follows: for teachers 95, non-conformist ministers 96, Church of England clergy 101, physicians and surgeons 103, authors and editors 104, policemen 153, postmen 159, carmen 207, dock laborers 231, barmen 234, miners 258, and general laborers 438. It is a long

[1] The substance of a portion of this chapter was presented at the Sixth International Neo-Malthusian and Birth Control Conference, March 26, 1925, at New York City.

way from the 95 children per 100 married couples of the teachers to the 438 per 100 of the general laborers.

Or for four large European cities consider the figures of Bertillon of an earlier date (1897), but not essentially different from present conditions. They show, as seen in Table XI, that while, on the average 1000 women between the ages of 15 and 50 living in very poor quarters of these four cities had annually 153 births, 1000 women living in very rich quarters had but 53.75 births, or only about one-third as many.

TABLE XI

BIRTHS PER 1000 WOMEN, AGED 15 TO 50, PER ANNUM, IN DIFFERENT QUARTERS OF LONDON, PARIS, BERLIN, AND VIENNA. (BERTILLON)

Classes of population	London	Paris	Berlin	Vienna
Very poor	147	108	157	200
Poor	140	95	129	164
Comfortable	107	72	114	155
Very comfortable	107	65	96	153
Rich	87	53	63	107
Very rich	63	34	47	71
Average per 1000 women	109	80	102	153

That the same situation prevails today is indicated by the figures regarding the birth rates in different suburbs of Berlin in the years 1910 and 1924, given by Freudenberg (164).

Finally consider the different racial groups in the United States as shown in Appendix Table 20.

The rates for the Italian and the Other Foreign groups are enormously higher than those for the other national groups, and particularly higher than those for women born in the United States. A considerable part, though probably not all, of the very great excess of the rates in the Italian and Other

Foreign groups is due to a more favorable age distribution of the women in these groups.

Another and more instructive aspect of the United States data is given by the figures shown in Table XII. In this column A gives the birth rates for native born mothers by states, as in the first column of Appendix Table 20. Column B gives the estimated value of all property, per capita of population, in 1922, in the same states (129).

TABLE XII

(A) Birth rates of Native Born Whites Per 1000 Enumerated Female Population 1920 and (B) Per Capita Estimated Value of All Property, 1922, by States.

State	Birth rate	Per capita value of all property
Connecticut	31.2	$3614
Massachusetts	33.2	3243
New York	33.5	3436
District of Columbia	33.9	3879
California	34.7	4007
New Hampshire	37.0	3074
Vermont	39.1	2389
Oregon	39.5	4182
Ohio	39.9	3048
Washington	41.0	3600
Maine	41.3	2586
Pennsylvania	42.0	3187
Indiana	43.8	2942
Wisconsin	45.4	2887
Kansas	46.4	3493
Maryland	47.1	2665
Michigan	47.7	2899
Minnesota	48.5	3442
Nebraska	49.8	4004
Kentucky	55.1	1459
Virginia	56.7	2050
South Carolina	59.1	1385
North Carolina	64.2	1703
Utah	64.5	3247

It is at once evident that generally in this Table XII as the birth rate goes up the average per capita wealth goes down. The net correlation between the birth rate per 1000 women and the average per capita value of all property, when population (as of 1920) is held constant — in order to free the result of spurious correlation — is,

$$r_{xy \cdot z} = -0.615 \pm 0.086 \quad (1)$$

This is not only a significant, but a relatively high correlation.

This result is depicted graphically in Fig. 29. This is based upon breaking the whole series of 24 states given in Table XII up into six groups of four states each, and then for each of these six sub-groups calculating the mean birth rate and the mean per capita wealth. In calculating these sub-group means the wealth per capita for each state was weighted in proportion to the 1920 total population of that state, and the birth rates were weighted in proportion to the female populations. The data of Fig. 29 are, then, true weighted averages. The purpose of this procedure is simply to smooth the detailed state figures. The data from which Fig. 29 is plotted are given in Table XIII.

TABLE XIII

WEIGHTED MEANS, FOR SIX GROUPS OF STATES, OF THE DATA OF TABLE XII.

State group	Weighted mean birth rate	Weighted mean per capita wealth
I (Connecticut, Massachusetts, New York, District of Columbia)	33.2	$3417
II (California, New Hampshire, Vermont, Oregon)	36.0	3838
III (Ohio, Washington, Maine, Pennsylvania)	41.2	3145
IV (Indiana, Wisconsin, Kansas, Maryland)	45.3	2991
V (Michigan, Minnesota, Nebraska, Kentucky)	50.0	2822
VI (Virginia, South Carolina, North Carolina, Utah)	60.5	1840

Kohlbrugge (149, p. 637) gives some statistics showing the same relation. From 4758 city marriages (from Dortrecht and Rotterdam) and 4685 marriages of persons living in the country, he calculated the number of births (including still-

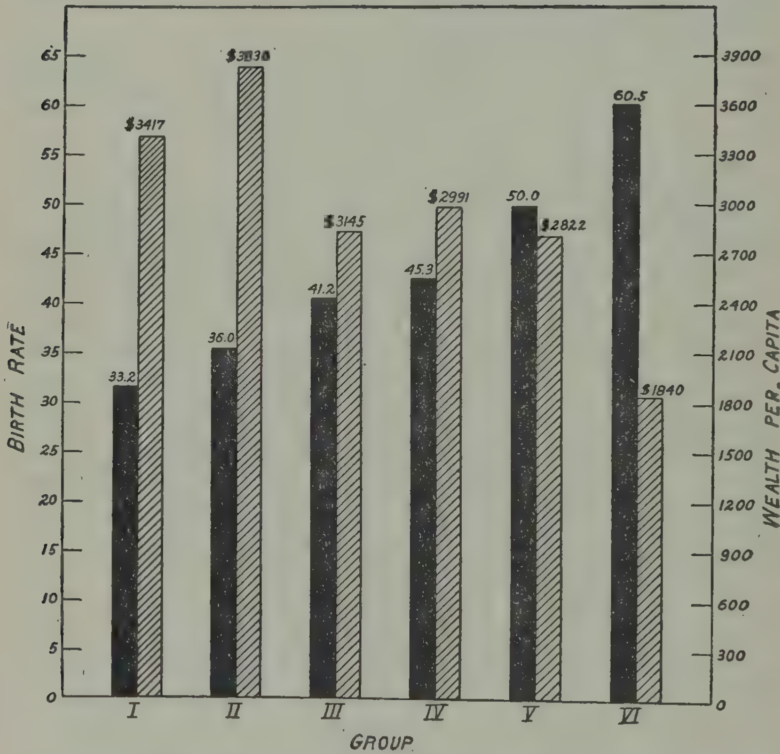

Fig. 29. Bar diagram showing the relation between birth rate and per capita wealth. Data from Table XIII. The solid bars indicate birth rate, and the cross-hatched bars per capita wealth.

births) per 1000 families. All the marriages were presumably completed (or nearly so) from the reproductive standpoint. He then divided the material into four groups on the basis of

economic well-being. He does not define the limits of his economic classes. The results were as follows:

	Births per 1000 families			
Economic Group	I (Poorest)	II	III	IV (Richest)
City families	561	521	435	418
Country families	519	509	475	450

The decline of the birth rate with increasing riches is evident in both groups.

The evidence so far presented, of which a great deal more might be adduced, is, I think, sufficient to establish that, in general, there is a negative correlation between birth rate and wealth, or a positive correlation between birth rate and poverty. But poverty in turn is a substantially accurate relative measure of the *quality* of the physical and biological environment of human beings. The environment of the very poor is hard in every respect; food, shelter, work and fatigue, recreation, all these elements are far harsher in their impact upon human beings stricken with poverty than upon people of wealth. The very poor man cannot control his environment to the benefit of his happiness and well-being except in a degree slight and insignificant as compared with that in which the rich man can control his. Without for the present inquiring at all as to why the poor man came to be poor, or continues to be so, it is the plain fact that the very poor live in a physically and biologically harsh and inadequate environment, while something about the opposite of this is true of the very rich. So then the matter may be stated in this way: it appears to be generally the fact that there is an inverse or negative correlation manifest amongst human beings between the birth rate and the biological quality or adequacy of the environment for the maintenance of human comfort and well-being. The nature of this correlation is that the better the environment, the more comfortable and higher the standard

of living, the lower the birth rate and *vice versa.* There is nothing novel about this result. It has been observed by many persons. I have here merely brought forward a little further quantitative evidence regarding the matter.

II

The same kind of correlation is probably found in some degree among animals lower in the evolutionary scale than man, and also among plants. When thrown into a harsh or abnormal environment which threatens but does not immediately lead to the extinction of all the individuals, and therefore of the race, it has been observed that some organisms tend to respond by curtailing vegetative processes and organs and greatly increasing reproductive processes and organs. It is impossible here to resume all the evidence on this point nor is it necessary. A detailed and clear statement of the point is given by Hugh Miller (130), a part of which I shall quote. In the course of an account of his experience on a job as stone-cutter in a quarry on the West Coast Highlands of Scotland, he says (p. 277–279):

" For about six weeks we had magnificent weather — clear, sunny skies, and calm seas; and I greatly enjoyed my evening rambles amid the hills, or along the seashore. I was struck, in these walks, by the amazing abundance of the wild flowers which covered the natural meadows and lower hill-slopes — an abundance, as I have since remarked, equally characteristic of both the northern and western islands of Scotland. The lower slopes of Gairloch, of western Sutherland, or Orkney, and of the northern Hebrides generally — though, for the purpose of the agriculturist, vegetation languishes, and wheat is never reared — are by many degrees richer in wild flowers than the fat loamy meadows of England. They resemble gaudy pieces of carpeting, as abundant in petals as in leaves.

Little of the rare is to be detected in these meadows, save, perhaps, that in those of western Sutherland a few Alpine plants may be found at a greatly lower level than elsewhere in Britain; but the vast profusion of blossoms borne by species common to almost every other part of the kingdom, imparts to them an apparently novel character. We may detect, I am inclined to think, in this singular floral profusion, the operation of a law not less influential in the animal than the vegetable world, which, when hardship presses upon the life of the individual shrub or quadruped, so as to threaten its vitality, renders it fruitful on behalf of its species. . . . And in the gay meadows of Gairloch and Orkney, crowded with a vegetation that approaches its northern limit of production, we detect what seems to be the same principle chronically operative; and hence, it would seem, their extraordinary gaiety. Their richly blossoming plants are the poor productive *Irish* of the vegetable world; for Doubleday seems quite in the right in holding that the law extends to not only the inferior animals, but to our own species also. The lean, ill-fed sow and rabbit rear, it has been long known, a greatly more numerous progeny than the same animals when well cared for and fat; and every horse and cattle breeder knows that to overfeed his animals proves a sure mode of rendering them sterile. The sheep, if tolerably well pastured, brings forth only a single lamb at a birth; but if half-starved and lean, the chances are that it may bring forth two or three. And so it is also with the greatly higher human race. Place them in circumstances of degradation and hardship so extreme as almost to threaten their existence as individuals, and they increase, as if in behalf of the species, with a rapidity without precedent in circumstances of greater comfort. The aristocratic families of a country are continually running out; and it requires frequent creations to keep up the House of Lords; whereas our poorer

people seem increasing in more than the arithmetical ratio. In Skye, though fully two-thirds of the population emigrated early in the latter half of the last century, a single generation had scarce passed ere the gap was completely filled; and miserable Ireland, as it existed ere the famine, would have been of itself sufficient, had the human family no other breeding-place, to people in a few ages the world. Here, too, in close neighborhood with the flower-covered meadows, were there miserable cottages that were swarming with children — cottages in which, for nearly the half of every twelve-month, the cereals were unknown as food, and whose over-toiled female inmates did all the domestic work, and more than half the work of the little fields outside."

This whole viewpoint was vigorously combated by Spencer in his "Principles of Biology." But I think that his argument is not entirely convincing in respect of the main point, chiefly because he overlooks two things. The first of these is that the "abnormal plethora" in respect of food which he admits reduces fertility, is precisely the usual thing among the well-to-do in civilized human society. The second is that the superior fecundity and fertility of domesticated animals generally has much more probably been mainly the result of breeding for that characteristic than the result of feeding. Let any one who doubts this try by any process of feeding whatsoever to make Pit Game hens, for example, as good layers as Plymouth Rocks or White Leghorns.

While obviously in the present state of knowledge, no stress can be laid upon such a direct correlation between harshness of environment and rate of reproduction among animals and plants living in a state of nature, it seems probable that within limitations it does exist, and it seems of interest to mention it in connection with the present discussion, although it has no essential bearing upon the argument. An interesting, and care-

fully worked out experimental demonstration of a correlation of this sort has recently been recorded by Hammarlund (160), who shows that in the case of the mildew *Erysiphe communis* a greater number of spores per conidiophore develops in dry air (which represents a relatively unfavorable environmental condition for this form) than in moist air. Furthermore, the energy of germination is greater in the dry air conidia than in the moist air conidia. The formation of ascospores by yeasts is another primitive example of the same law. Chapman (165) says: "It would seem that spore formation is a provision on the part of Nature for securing the persistence of the species under conditions in which active budding is impossible. It appears, at any rate, to play an important part in the hibernation of yeasts, rendering it possible for them to live through the winter in soil, or on surfaces from which very little nutriment can be extracted." The general ecological observation that the tropical jungle flora is broadly characterized by great profusion of vegetative parts (leaves, etc.), while the Arctic flora is noted for the profusion of flowers, has bearing upon the point. The whole matter wants more thorough investigation than has yet been accorded it.

III

It is probable that the very harshness and inadequacy of the human environment which is the inevitable and indeed necessary concomitant of real poverty, tends perhaps directly, and certainly indirectly through psychological reactions, to produce a high birth rate among human beings. And, on the other hand, it seems to me to be equally clear that the probably super-optimal environment, biologically speaking, which even moderate wealth is able to command, tends both directly and indirectly to low fertility and even a good deal of actual sterility. Not only do the well-to-do have many other pleasur-

able outlets for nervous energy besides the sexual, but also they are generally acquainted with the best methods of contraception. Both of these factors tend to lower the class birth rate. All wealth is of course relative. I am not referring solely to the glittering opera patron of the metropolis. As compared with real poverty the environmental situation of what are called middle-class people — even of college professors — is biologically adequate.

The implication of the preceding paragraph is that there is a correlational nexus or pathway of the following sort. Relative wealth makes possible, and is correlated with a relatively favorable and easy environment for human existence. On the physical side this means better food, housing, etc. On the psychological side it means more avenues and opportunities of recreation, more varied intellectual interests, and generally wider outlets for nervous energy. These things in turn, it is suggested, correlate with less frequent sexual activity, and with a lower birth rate. At the other economic extreme we have the opposite picture. Poverty correlates with a poor environment for human existence, with poor food and housing, and on the psychological side restricted opportunities for recreation, narrow intellectual interests, and generally only two reliable outlets for the speedy and satisfactory relief of nervous tension, namely alcohol (which now is at least theoretically banned) and the sexual relation. This situation correlates with more frequent sexual activity and a higher birth rate.

In support of this suggestion as to the correlations involved, there will be presented in the next chapter some data on the actual frequency of sex activity in groups of the population of different economic, cultural, and intellectual levels, and further discussion of this particular point may therefore be deferred until the results presented in Chapter VIII are in hand.

The eugenic aspect of the differential birth rate is the one which has excited the greatest interest. Some early eugenic studies, especially those of Professor Karl Pearson and his students, demonstrated the fact that various sorts of obviously undesirable persons had high fertility rates, while some equally obviously desirable persons had low fertility rates. This situation he rightly regarded as racially unsound in principle. But a curiously inverted deduction from these results seems to have become current. The doctrine appears to have gained wide acceptance that somehow high fertility in a group is *in itself* an indication of probable racial unfitness. In actual fact nearly every group of persons that I can think of which does show high fertility seems to be quite generally regarded by eugenists as socially and biologically undesirable. They are alleged to be *genetically* unfit. It has even been suggested that there is a gene, or combination of genes, for poverty — that a man is poor only because he inherited stupidity, lack of ambition, or some other similar traits of character. Now, while I am certainly no violent environmentalist, I gravely doubt if such a position is tenable. The best evidence against it, I think, is the overwhelmingly common fact that the ranks of the rich and the well-to-do (which also generally mean the educated and cultured) are frequently recruited from the ranks of the poor. Yet it is apparently the *poor,* and *not merely* the morons and defectives, that have high birth rates. There are in the world a fair lot of rich morons and rich defectives (some uncharitable persons would even say a good many). But in my observation when morons are rich their birth rate is not high. It is just about that of the rich in general. And similarly the birth rate of the *poor* moron or defective is not greatly different, so far as I can learn, from that of the poor in general. The shocking comparisons of the fertility of the Jukes and other such degenerate and defective

stocks are usually made with such groups as the Edwards family, or college men or women, who occupy an obviously different *economic* plane. Are such people as the Jukes more fertile than a group of honest and biologically sound workingmen *of as nearly as possible the same economic status?* This question I think has not received the consideration it deserves.

What seems to me to be in some part at least essentially the same point as that of the preceding paragraph is made by Dublin (134) in his recent address as President of the American Statistical Association where he says: " When we have eliminated the upper and lower 10 per cent of our population, there is not sufficient indication of serious differences in innate ability among the remaining 80 per cent to justify the current fears and warnings against their deliberate participation in parenthood. They are neither spectacularly able nor do they abound in defects. If they lack the brilliance which would single them out for special distinctions, they have usually other compensating, valuable and attractive qualities. They are just plain folks carrying on the world's work. We see on all sides clear evidence of the ability of ordinary people to give birth to children capable of the highest achievements as opportunity and environment release their power. Our social organization by its very complexities and the perfection of its mechanical foundations, is conducive to stimulating the innate abilities of men from all walks of life, which in a less well-organized society might go to waste. Throughout all ages the leaders of mankind have come predominantly from homes which at first sight seemed most unpromising and commonplace. Will not the leadership of the next generation come, as it always has in the past, from that source? "

While one must deprecate in this connection such superlative expressions as " highest achievements " and " always has in

the past," still I think that the general idea contained in this paragraph, if stated in more conservative language, would be extremely difficult to controvert successfully.

Before leaving this part of the discussion I wish to make it as clear as possible, in order to forestall the otherwise certain misrepresentation of my views, that I do not regard economic factors as the only ones influencing human birth rates. Nothing could be farther from my position. I am merely trying to show that the evidence indicates that there seems to be generally a significant correlation between variations or differences in economic status and variations in birth rate. This fact has been pointed out by a number of students of the problem, notably Yule (111). But that other non-economic social factors such as religion, and various biological factors, also may play a role, and an important one in some cases, no sensible person would deny.

IV

If the facts presented in this chapter regarding the relation between poverty and the birth rate are in any degree generally true, and I think investigation will show that they are in civilized societies, the thought at once suggests itself that it is not only desirable in the eugenic interest of the race to cut down, indeed completely extinguish, the high birth rate of the unfit and defective portions of mankind, but it is also equally desirable because of the menacing pressure of world population, to reduce the birth rate of the poor, even though that unfortunate moiety of humanity be in every way biologically sound and fit. This contention, I think, needs no extended argument. A wealth of evidence regarding the social and biological consequences of the growth of population has been collected, and convincingly and brilliantly presented by Dr. E. M. East (139), in his recent book "Mankind at the

Cross-roads." Another recent book of the same tenor which will repay reading is by Swinburne (140).

The position of the whole world on its logistic curve is shown graphically in Fig. 30. The figures on which this diagram is based will be found in Pearl (27, pp. 631–632).

The equation of the logistic curve of Fig. 30 is as follows:

$$y = 445.5 + \frac{1580.5}{1 + 5.342e^{-0.0243x}} \tag{li}$$

While all figures for world population are necessarily estimates in some part, I have included in Fig. 30 only those which seem on the whole to be the most reliable. And it can scarcely be supposed that they are so grossly in error as materially to alter the shape of the logistic curve from what it would be if the true facts were known. It is apparent from Fig. 30, if the estimates of world population on which the logistic is based are in any reasonable degree reliable, that the world is well along towards the upper limit of population on its present cycle of growth. The upper asymptote of the world population, as predicted by the logistic, is 2,026 millions. Penck (141) estimates the "potential" world population at 8,000 millions, a much higher figure than that given by this logistic curve, but I am unable to convince myself that his estimate is justified by the evidence.

Certainly those students of the population problem who have concerned themselves especially with the human food supply which can be produced on the face of the earth reach no such large estimate of population potentialities as does Penck. Already marked alterations in agricultural matters are appearing as the result of population growth. It would be apart from the purpose of the present study to go into the evidence along this line in any detail here, and it has already been dealt with thoroughly by other workers, notably East (*loc.*

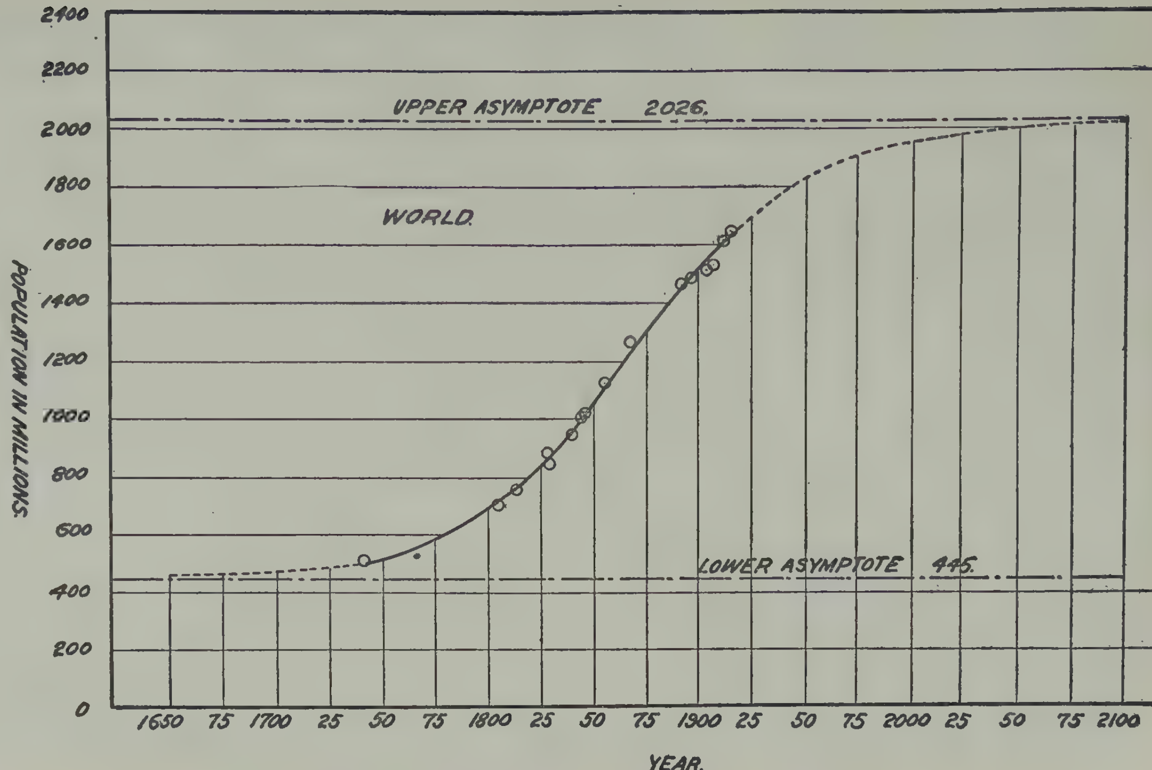

FIG. 30. The growth of the population of the world.

cit.). But as an indication of changes which are going on relative to human food production which are of grave import for the future I insert Fig. 31 from a recent paper by the distinguished student of the problems of world agriculture in relation to population, Dr. O. E. Baker (148). The legend fully explains the point.

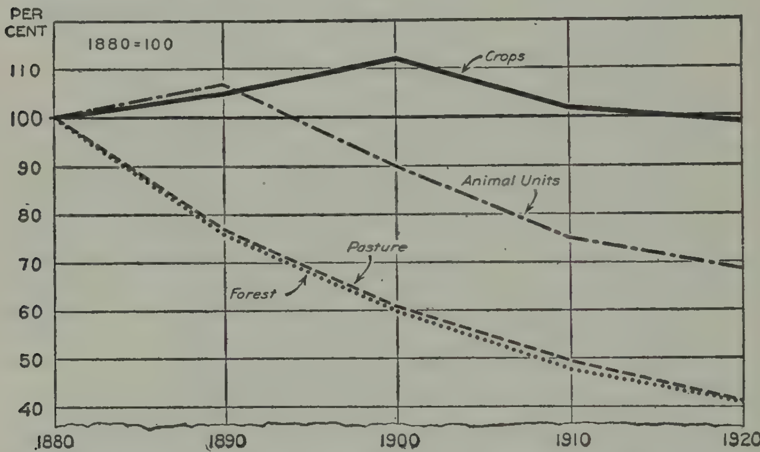

Fig. 31. Trend of per capita acreage of crops, pastures and forest, and amount of live-stock, United States, 1880–1920. With the progress of population crop land tends to increase at the expense of pasture and forest land. The per capita acreage of crops in the United States increased 12 per cent between 1880 and 1900 and then decreased to an amount in 1920 one per cent below that in 1880. The per capita acreage of both pasture and forest lands, on the other hand, have declined steadily since 1880 and are now only 40 per cent as great as 40 years ago. The per capita amount of live-stock increased till 1890, and has since decreased at almost as rapid a rate as pasture. The general trend is toward more bread and less beef. (Graph from 1923 Yearbook of U. S. Dept. of Agriculture, and Baker (148).)

Baker (*loc. cit.* pp. 50–52) sums up the population outlook in the following words, which seems to me to be a very sound and conservative presentation of the case: " Agriculture, not mining or manufacturing, will eventually determine the limits of the world's population. The reserves of coal and iron are

adequate to support our civilization for many hundreds, perhaps for several thousand years. Industry can continue to develop and give employment to increasingly larger numbers of workers far beyond the time when the arable land will have reached such a stage of productivity that further intensity of cultivation is unprofitable. Not many people will starve; but, as in Europe recently, the death rates will rise, especially the infant death rates, while the hours of labor will lengthen and the lower standard of living will make people more susceptible to disease.

"It is certain that if the population of the United States continues to increase for more than another century as it has during the past century there is no means by which the present standard of living can be maintained, except by importation of foodstuffs from other lands, — which will need their foodstuffs even more than we. And looking forward 200 or 300 years, which is a shorter span of time than that elapsed since the settlements at Jamestown and Plymouth, it seems necessary to recognize not only a stationary population in this country, but also throughout the world. Whether this stationary state will be one of misery for the majority of the people, as in China and India today, or one of well-being and happiness will depend largely upon voluntary restriction of population.

"Nevertheless, it is clear that if occidental civilization during the next 100 years relapses into the condition of poverty and political corruption that characterizes most of the orient, the failure will arise from the dying out of the more capable people, from decline in individual initiative, and from neglect to use the scientific knowledge that has accumulated and the agricultural implements that have been devised, rather than from the niggardliness of nature. There is left to the white man a century of grace, in which to develop that rational

direction and control over himself that he has so successfully applied to nature during the past century. The trend of birth rates in the United States, Canada, and Australasia, considered in conjunction with the natural resources, is encouraging; but for nearly all other countries the prospect is not so hopeful."

V

The efforts of the eugenists to correct the evils of the differential birth rate, by endeavoring to induce the socially, economically, and in some part biologically, superior classes to reproduce more freely, as a sort of transcendental social duty, have not met with any discernible success, and in my opinion are not likely to. When the issue which is to determine human behavior is drawn between the present comfort, happiness and well-being of the reproducers on the one hand, and the indefinitely future welfare of society in general, or the race or state, on the other hand, he would seem indeed a simple-minded, not to say fatuous optimist who supposes that the latter will outweigh the former. It will do nothing of the kind. It was a worldly wise if not very altruistic sinner who first raised the question as to what posterity has ever done for us. As was recently pointed out editorially (142) in England: " A man may be induced by patriotic motives to die for his country, but hardly to procreate children for her, unless he can be convinced that those children will find places to fill at least as good as that he occupies. Rhetoric about race suicide, the decline of the empire, and so on, will never be accepted by the potential parent as a substitute for an economic guarantee."

But if it is not possible to make desirable people have more babies, why not try teaching other people how to have fewer? This is precisely the position of the birth control movement, and it seems to me to offer the only hope of altering for the

better the existing differential inequalities in the distribution of the birth rate. Many persons object to the birth control movement on the ground that it widens already undesirable class differences in the birth rate, because the intelligent and educated people all practice it while those with the high birth-rates will not. But will they not? I am not nearly so sure of this as I once thought I was. The tightest of legal barriers prevents now the diffusion of knowledge as to methods of contraception. The poor in particular are shut off from learning what is the best information available in these directions. At the same time the poor man is quite as keen as anybody else for the pleasures of sex. As has already been pointed out above it is his chief resource as an outlet for the extra nervous tension begotten by the harsh environment to which he is more or less doomed. Is it any matter of wonder, things being legally as they are, that the poor have a high birth rate?

That such a view of the matter is coming to be taken by persons who cannot by any chance be labelled birth control propagandists is indicated by the following quotation from a recent editorial note in *Nature* (143):

"That some form of birth control is the only means of regulating the tendency of the population of Great Britain to increase beyond the limits of our food supply is a conclusion which has forced itself on more and more thinkers, both in the biological and economic spheres. . . . After all, there is no getting away from the fact that the practice of birth-control is widely spread among the middle classes, and to deny the knowledge of the means to the poor, who need it far more than the middle classes do, is a proceeding which no parliamentary language is strong enough adequately to criticise."

CHAPTER VIII

HUMAN BEHAVIOR AND THE BIRTH RATE

I

THE purpose of this chapter is in the first instance to present some of the results of a biometrical analysis of a considerable mass of unique data on normal human sex behavior. The pertinence of this material to the present discussion will appear specifically as we proceed, but in general terms is evident *a priori*. Increase of human populations by excess of births over deaths is the physiological consequence solely of the successful mating of human beings of the two sexes. Owing to prohibitions from external sources, on the one hand, and to inhibitions of subjective origin, on the other hand, normal human sex behavior has been extremely little investigated or discussed in scientific literature. There is a wealth of material on the pathological aberrations of the sex instinct, in its magnitude probably out of all true proportion to the real importance of this sad aspect of the subject. But regarding normal sex life even the most simple and basic quantitative scientific data are almost totally lacking, and entirely so from the viewpoint of statistical adequacy.

The material to be presented in this chapter makes a definite, and I hope significant contribution to the filling of this gap in knowledge. The present data are by no means perfect or exhaustive. But within their limitations as to content they are substantially accurate, and furnish information which in any proper statistical sense has been entirely lacking hitherto. It may be possible through coöperation with hospital clinicians

greatly to extend the collection of data as time goes on, and broaden its scope. Pending this, however, it seems desirable no longer to delay the publication of the material already in hand.

II

This material consists of records for something over 250 men of the average frequency per month of coitus, by decades of age from youth to advanced years. The records were furnished by the persons themselves, under circumstances presently to be recounted. In order to safeguard absolutely the impossibility of identifying any particular individuals or group of individuals with the statistical records the source of the material as a whole cannot be stated. The following account must suffice, together with the personal guarantee of the writer, under whose supervision and critical scrutiny the records were collected, that they are accurate within the limits of human fallibility in matters involving the memory of past events.

The individuals furnishing the records are persons who had been successfully operated on for the relief of benign hypertrophy of the prostate gland. A year or more after recovery from the operation a follow-up questionnaire was sent to each of them for the purpose primarily of getting information as to the remote results of the surgical procedure. At the same time the opportunity was taken to ask each person for a somewhat detailed account of his sexual life history, particularly in respect of average sexual activity per month in the different decades of life. They were told that this information would be so handled that the subsequent identification of any individual with it would be impossible, and that it would be of great value in the study of the etiology of benign prostatic hypertrophy, and of other scientific questions. In something

over 250 cases the patient's gratitude for the relief he had obtained from the surgical treatment was so great that he was willing to, and did in fact, go to a great deal of trouble to answer carefully, honestly, and to the very best of his ability, the questions asked. The original questionnaires, in many cases carrying detailed written statements in support of the numerical data, furnish in most instances their own guarantee of substantial accuracy. Wherever, on any ground whatever, there was reason to be suspicious of the accuracy of the returns the material was rejected from the tabulations presented here.

There are two chief points upon which the data will be criticised. These are (1) that since the persons to whom they relate eventually had benign hypertrophy of the prostate gland their sex life prior to the onset of this disease cannot be regarded as normal, and (2) that persons of advanced years, as all of these were at the time of making the records, cannot be supposed to remember accurately, even if they would, their habits in this regard of several decades earlier in life. They will be accused of magnifying or diminishing, depending upon their general temperament, the true facts of the case. The *a priori* logical cogency of both these criticisms must be fully admitted. But just because they are obviously cogent in the absence of further information, it is necessary at the outstart to discuss them fully, and bring into the record such pertinent ancillary information as exists.

Regarding the first point the following is to be said. This criticism is merely equivalent to asserting that there should be a control group of persons of the same age distribution, furnishing the same information, who never had hypertrophy of the prostate gland. This is, of course, not only true but obvious. If I had the data from such a group I should present them. It is my hope to get at some future time just such a

group, through coöperation with clinicians. But the present lack of such a control group should not lead one hastily to dismiss this study as of no value, for two reasons. In the first place logically the absence of a non-prostate control group merely means that we cannot generalize any conclusions reached beyond the category of persons who ultimately have benign hypertrophy of the prostate gland, and this we shall be careful not to do. The question of whether the sex activity of eventual non-prostatics is the same as, or different from, that of eventual prostatics is simply left in abeyance as incapable of answer at the present time. But greatly more important than this purely logical point is another which is biological in nature. A painstaking study of the present extensive material has failed to give any evidence that degree of sexual activity has any discernible influence in the etiology of benign hypertrophy of the prostate. As will presently appear there is the widest variation exhibited in this group of men in respect of the degree of sex activity as indicated by monthly frequency. But these differences in sexual activity are not at all correlated with either the severity of later prostatic symptoms, or with the amount of hypertrophy of the gland, or with the age at onset of prostatic symptoms, or with any other observed clinical manifestations of the disease. Those men exhibiting extremely low sex activity throughout life had prostatic hypertrophy just as surely and as severely as those with extremely high sex activity. In view of these facts I personally strongly incline to the view that, when a proper control group of non-prostatics is available, it will be found to give results substantially identical biometrically with those here presented for prostatics. But I offer this merely as personal judgment based upon admittedly inadequate evidence. The question can only be settled by getting the control group.

Regarding the second criticism, which relates to the intrinsic accuracy of the statements as to sex activity the following is to be said. The figures to be presented are *estimated average* monthly frequencies. Few men ever kept an accurate and detailed documentary record of such matters. But most men of even average intelligence, if they will only be honest, can state with very reasonable accuracy their *average* habits at different periods of life. This is all that the men in this group were asked to do, and all that they did do. Furthermore, taking the group as a whole, they were men of more than average intelligence.

The best evidence as to the substantial accuracy of the figures is found in the detailed study of the individual protocols and the accompanying correspondence. Unfortunately this cannot be presented here. But it is convincing. In the great majority of instances where the figure for a particular decade would strike one as abnormally high or low, there is an accompanying explanation, stating the true facts to the best of the reporter's ability. In some cases the direct statement is made, and probably the same thing is true of a good many more where no specific statement is made, that the figures given have been checked over and agreed to by the wife.

III

The total number of individuals included in the present discussion of the material is 257. These were all white men who had been married one or more times. The original material included some single men, but their number is too small to justify separate biometric treatment. In the interest of statistical homogeneity of the material it was thought advisable not to lump the single in with the married. So all of the tables and biometric constants presented in this chapter relate to married men only.

The age distribution of the whole group at the time of their operations is shown in Table XIV. The total of this table is 254, the three missing individuals lacking a precise statement of age at operation.

TABLE XIV

AGE AT OPERATION

Age group	Cases
45–49	3
50–54	19
55–59	49
60–64	61
65–69	58
70–74	53
75–79	9
80–84	2
Total	254

From the distribution of Table XIV the mean age at operation of this group is found to be 64.53 ± 0.29 years, and the median age 64.59 years. This mean value agrees reasonably well with that for cases of benign hypertrophy of the prostate in general (135), which is 66.72 ± .16 years, based on 977 cases. Of course, for reasons already stated above, the ages of the persons in Table XIV were higher at the time the present information was furnished than the age at operation.

The age at marriage of the 242 men in the group who stated this fact is shown in Table XV.

The two distributions of age at operation and at marriage, as given in Tables XIV and XV, are shown graphically in Fig. 32.

From the distribution of Table XV the mean age at first marriage of the men in this group is found to be 28.33 ± .28 years, and the median age 27.39 years. From these values

and the polygons of Fig. 32 it is evident that while the distribution of ages at operation is practically symmetrical about

TABLE XV

AGE AT MARRIAGE

Age group	Cases
15–19	9
20–24	67
25–29	94
30–34	40
35–39	21
40–44	5
45–49	2
50–54	3
55–59	1
Total	242

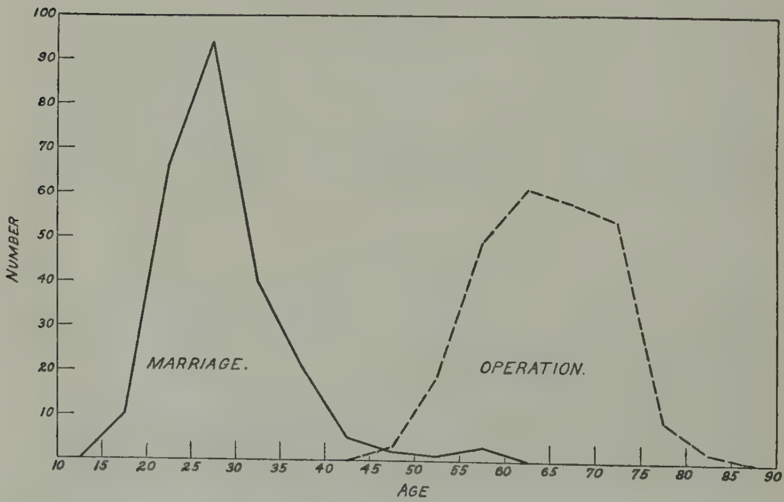

FIG. 32. Frequency polygons for age at marriage (solid line) and age at operation (broken line).

its mean, the distribution of ages at marriage is somewhat skew in the positive direction.

Table XVI gives the integral form of the distribution of ages at marriage in percentage terms. The data will be needed in this form in the subsequent discussion.

TABLE XVI

PERCENTAGES OF MEN IN THE GROUP MARRIED AT OR BEFORE THE STATED AGE

Age	Per cent married
20	4
25	31
30	70
35	87
40	95
45	97.5
50	98.3
55	99.6
60	100.

IV

In dealing with the present material I propose first to exhibit its general characteristics, and then proceed to the analysis of it which is particularly relevant to the subject with which this book deals. In Appendix Table 21 are shown the observed distributions of average frequency of coitus per month, by decades of age. It should be explained that the reason for the different totals for the different decades of life is that not every individual gave information as to all the decades. In this table both absolute and percentage distributions are presented.

The percentage columns of Appendix Table 21 give an interesting and illuminating picture of the normal sex habits of a group of men, all of whom were married at some time.

As would be expected an average frequency of more than 30 per month, or one per day, is extremely rare. But higher frequencies than this do occur often enough to show that apparently there really does exist a small but definite "sexual athlete" class of men, of which Casanova may be regarded as the classic prototype in literature. Knowing that these high frequencies are sure to be questioned on the point of accuracy, special pains have been taken to get from the individual in each such case detailed supporting evidence for the figures returned where such was not originally furnished. A critical study of this evidence makes it as certain, in my judgment, that these exceptional returns are substantially correct, as anything based upon human testimony can be.

In order to make the meaning of the figures more apparent Table XVII has been prepared, by accumulating the percentages into broad groups. The summations of Table XVII are made within the following limits from Appendix Table 21. A frequency of 90 per month or over is placed in the class "Three times a day or oftener." Frequencies of 60 or more per month are put in the next class of Table XVII. Frequencies of 30 or more per month constitute the "Once a day or oftener" class. Frequencies of 15 or more per month constitute the "Every other day or oftener" class. Frequencies of 10 or more per month make up the "Every third day or oftener" class. Finally, frequencies of 5 or more per month are assembled in the class "Once a week or oftener." This last class of Table XVII is obviously not precisely accurate, but the class divisions of Appendix Table 21 were such as to make any nearer approximation impossible. At the worst the error is not great.

The precise manner in which this table is to be read is as follows: Of the 213 men reporting for the decade 20–29, there were 8.5 per cent who, during that age period, indulged in

TABLE XVII

THE PERCENTAGES OF A GROUP OF 257 MEN SHOWING THE INDICATED AVERAGE DEGREES OF SEX ACTIVITY AT DIFFERENT AGE PERIODS

Frequency	Under 20	20–29	30–39	40–49	50–59	60–69	70–79
Three times a day, or oftener .	0	1.0	0.4	0	0	0	0
Twice a day, or oftener.......	0	1.9	1.6	0.4	0	0.5	0
Once a day, or oftener	3.8	8.5	7.7	4.8	3.2	1.0	0
Every other day, or oftener...	11.5	26.9	27.1	22.7	12.9	3.6	0
Every third day, or oftener ...	26.1	45.7	49.8	42.5	24.2	13.0	3.8
Once a week, or oftener.......	34.5	68.2	80.2	74.6	59.0	31.3	8.9

coitus on the average once a day or oftener than once a day. Similarly, of the 191 men reporting on the decade 60–69, there were 31.3 per cent who, during that age period, indulged once a week, or oftener than once a week. These examples will make clear how the whole table is to be read.

The data of the last four lines of Table XVII are shown graphically in Fig. 33.

I think the thing which strikes one first and most forcibly from Table XVII and Fig. 33 is the extreme smoothness of the curves. In part this smoothness is a result of the process of summation, but quite beyond this factor the general smooth sweep of the curves furnishes some statistical evidence of the essential accuracy of the basic data.

All the phenomena of human biology are extremely complicated, and the one we are here dealing with is in some respects one of the most complex in the whole range. In consequence anything in the nature of dogmatism in attempting to interpret the form of the curves in Fig. 33 will be distinctly out of place. But with this caution in mind it will be useful to attempt some analysis.

The general course of the curves indicates, if taken at its apparent or face value, that the sexual activity in this group

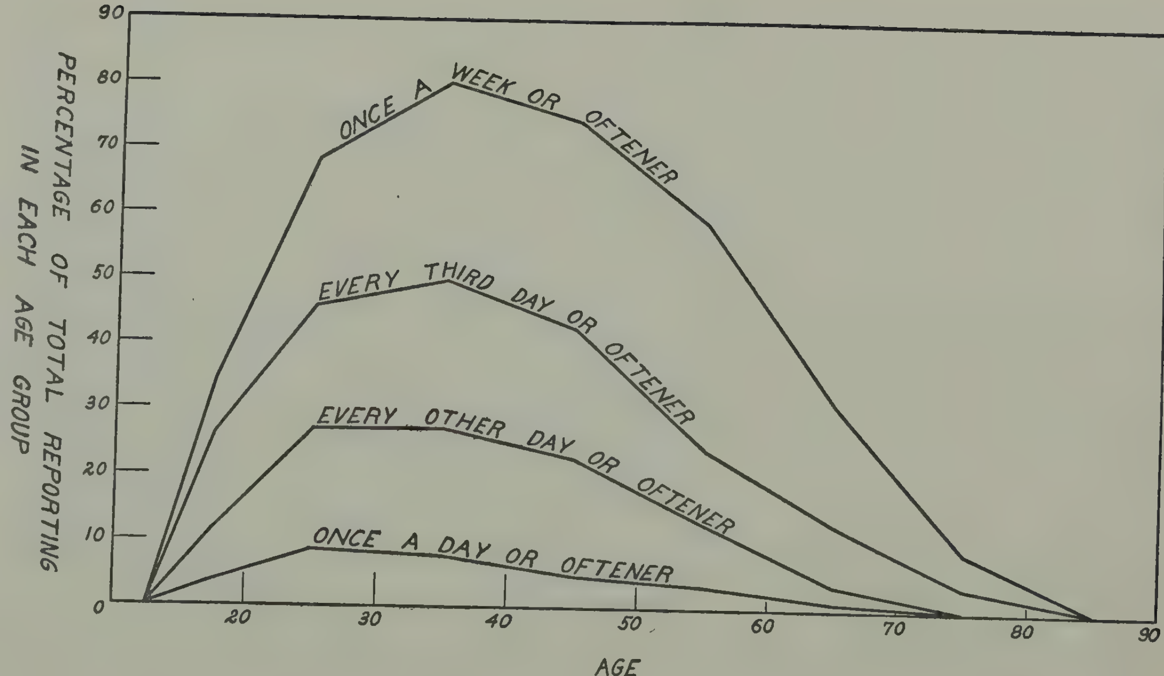

FIG. 33. Showing the per cent of the total number of men reporting in each age group who had the indicated degree of sex activity. (The age group 10–19 is centered at 17.5 for obvious reasons).

of men began at a relatively low level in the years prior to the twentieth, rose rather rapidly to its maximum in the decade of age from 30 to 39, and then much more slowly declined to a very low point in the decade 70–79. The descending limb of the curve offers no particular difficulty in interpretation. It is what would be expected as one of the evidences of senescence. By age 35 Table XVI shows that 87 per cent of the men in the group were married, and by age 40 the percentage had reached 95. So that the extraneous factor of lack of opportunity cannot have been operating in any significant degree to produce the declining frequency of the years after 35. I think it may with reasonable safety be concluded that the declining limb of the curves of Fig. 33 is an expression almost solely of the physiological changes of senescence. I have not overlooked the factor of widowerhood tending to produce a lowering of the curves in the later years. But in this particular sample of material this factor is not a statistically significant one.

The case from age 15 to 35 is by no means so simple. Table XVI shows that but 4 per cent of the men making up this group were married by age 20. It is entirely reasonable to suppose *a priori* that the low frequency exhibited in this age period is in part and probably mainly an expression of an essentially social factor — lack of opportunity — rather than of anything physiological. That this is in fact the case, and that the true physiological maximum of sex activity is earlier than the third decade of life is indicated by the following figures. Table XV shows that there were 67 men in the group who married between the ages of 20 and 24 inclusive. These men all had, therefore, unrestricted legitimate opportunity for sex activity from an average age of 22.6 years (by actual calculation) on. The average frequencies per month for this group of 67 men, by decades from age 20 on are as follows:

TABLE XVIII

SEX ACTIVITY OF 67 MEN MARRIED IN AGE PERIOD 20–24

Decade of age	Average frequency per month
20–29	14.7
30–39	12.9
40–49	9.1
50–59	6.3
60–69	3.1
70–79	1.2

These averages are shown graphically in Fig. 34.

These data show that with approximate equality of opportunity at the different ages the peak of activity is in the 20–29 decade and that thereafter there is a steady decline. The data for ages at marriage earlier than 20 are too meager to warrant any definitive conclusions. However, it is worthwhile to see what the facts are regarding the 9 individuals who married before age 20. The average age at marriage of these 9 was 18.6 years. The record of their sex activity is shown in Table XIX.

TABLE XIX

SEX ACTIVITY OF 9 MEN MARRIED IN AGE PERIOD 15–19

Age period	Average frequency per month
15–19	21.8
20–29	17.3
30–39	15.0
40–49	13.0
50–59	10.6
60–69	7.6
70–79	2.7

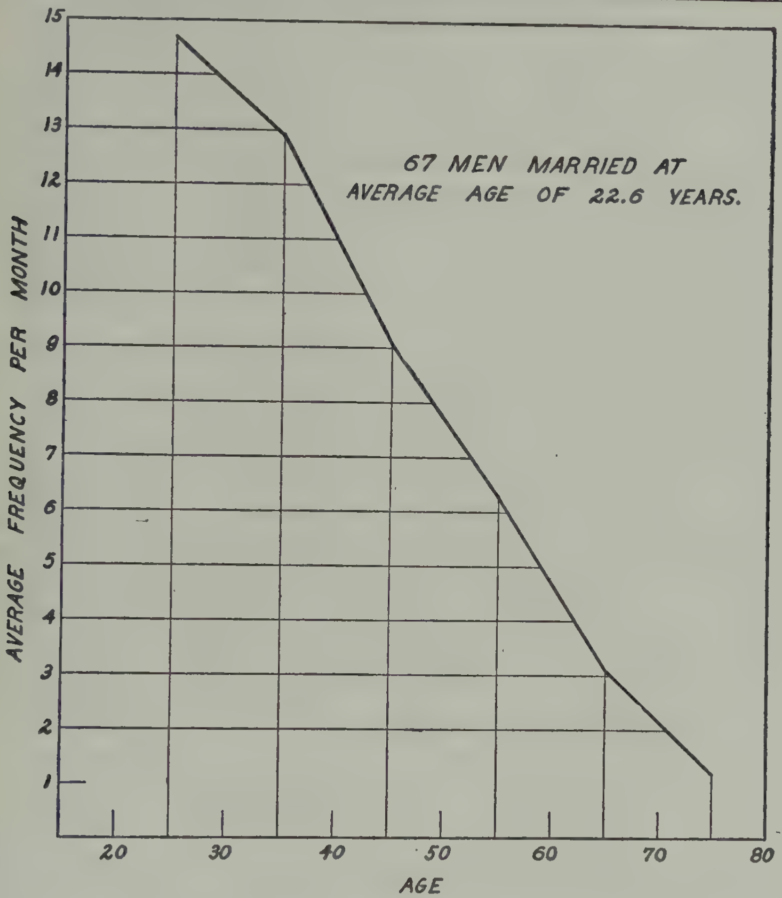

FIG. 34. Average sex activity by decades of age in a group of 67 men all of whom married between the ages of 20 and 24 inclusive.

This table clearly suggests that with unrestricted legitimate opportunity the peak of sex activity is prior to age 20. It seems quite certain that the peak indicated to be in decade 30–39 by the figures of Table XVII is a spurious result due to lack of equality of legitimate opportunity.

Another point of considerable interest emerges from a comparison of Table XIX with XVIII. It is that in each age period from 20 on, where comparisons may be made, the average monthly frequencies are higher in Table XIX. That is to say the men who married young (before age 20) exhibited throughout life a higher degree of sexual activity at corresponding ages than did those men who married between 20 and 24 years of age inclusive. The thought suggests itself that this greater sex vigor was a definite factor in producing the marriage at an early age. It must be remembered, however, that the number in this experience marrying before 20 is very small, and any conclusion based upon their experience must be maintained with great caution and reserve.

The points which Tables XVIII and XIX raise are of so much interest that I am constrained to present one more table of the same sort. Table XV shows that there were 21 men in the group who first married between the ages 35–39 inclusive. Table XX shows their sex history. Their average age at marriage was 37.0 years.

TABLE XX

Sex Activity of 21 Men Married in Age Period 35–39

	Age period	Average frequency per month
Before marriage	15–19	3.9
	20–29	7.7
Marriage	30–39	13.7
After marriage	40–49	12.9
	50–59	9.2
	60–69	3.2
	70–79	.0

This table shows, first, the marked effect of lack of legitimate opportunity prior to marriage, and second, the evident lack of sex interest or vigor as compared with the group who married before age 20. But, on the other hand, comparison with Table XVIII shows that in the period from 30 to 59 the late marrying men of Table XX had higher monthly averages. A larger collection of data is necessary before it will be possible to settle the many questions raised by the present material.

V

It will next be desirable to examine the principal biometric constants derived from the distributions of Appendix Table 21. These are given in Table XXI. In this table the constants for the age periods 15–19 and 70 and over are omitted, because of meagerness of the data, and because it has been shown in the previous section that the data from the age period prior to 20 cannot be regarded as furnishing reliable information on trends. In Table XXI the mean, median, standard deviation and coefficient of variation were calculated directly from the raw data of Appendix Table 21. The values of mode and skewness tabled are those derived from the fitted curves.

TABLE XXI

BIOMETRIC CONSTANTS FROM THE DISTRIBUTIONS SHOWING FREQUENCY PER MONTH, GIVEN IN APPENDIX TABLE 21

Age group	Mean	Median	Mode	Standard deviation	Coefficient variation	Skewness
20–29	12.57 ± .65	9.01	2.37	14.06 ± .46	111.9 ± 6.8	+ .889 ± .057
30–39	12.78 ± .50	9.90	4.88	11.61 ± .35	90.8 ± 4.5	+ .803 ± .053
40–49	10.95 ± .38	8.77	5.03	8.96 ± .27	81.8 ± 3.8	+ .703 ± .052
50–59	8.23 ± .34	6.25	2.52	8.00 ± .24	97.3 ± 5.0	+ .821 ± .053
60–69	5.30 ± .30	3.61	1.27	6.19 ± .21	116.8 ± 7.8	+ .892 ± .060

The mean, or arithmetic average, frequency per month descends with age from 12.57 in the decade 20–29 to 5.30 in

the decade 60–69, with an insignificant increase in the decade 30–39.

The median, which is that value above and below which exactly one-half of the men in the group fall in their sex habits, shows the same general trend with age as does the mean, but the absolute values are much lower because of the marked positive skewness of all the distributions.

The mode, which is the constant indicating the most popular or fashionable event, or in other words the one which occurs most often, follows a somewhat different trend with age than does either the mean or the median. The highest modal frequency per month of 5.03 occurs in the age period 40–49. The absolute values of the mode are low in all cases, indicating again the extreme skewness of these distributions and the large influence of the small group of "sexual athletes" upon the arithmetic mean.

The relation of mean, median and mode in their trends is shown graphically in Fig. 35, plotted from the data of Table XXI.

The slight rise in mean and median from age 25 to 35 I am inclined to attribute to the cause discussed in the previous section, namely a larger percentage of the group have attained free opportunity by marriage, in the 30–39 age group. It is not so clear about the trend of the mode. There may be another factor at work there, but the present material is not sufficiently extensive to settle the point.

The variation in sex habits amongst the 257 individuals in this group is high, whether estimated in absolute terms by the standard deviation or relatively by the coefficient of variation. If, and insofar as, we may judge from this sample, men are from 2 to 3 times as variable in this respect as they are in dermal sensitivity (*cf.* Pearson, *Chances of Death,* Vol. I, pp. 293–377), from 3 to 4 times as variable as they are in

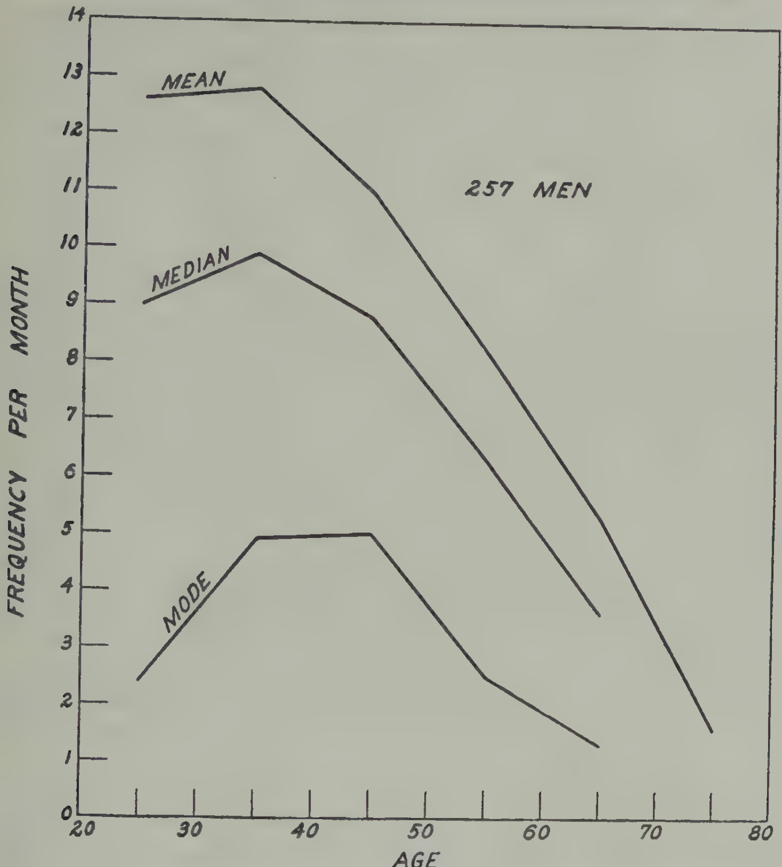

FIG. 35. Mean, median and modal values for sex activity at different ages.

keenness of sight (*ibid.*), from 4 to 5 times as variable as they are in swiftness of blow, and from 8 to 10 times as variable as they are in body weight. On the whole I should think this finding regarding the *relative* variability of sex habits is about what one would expect on general grounds. Complex psychological factors are the determiners of sex activity, and though

these psychological elements in the case may ultimately rest in some part upon endocrine secretions, still there is plenty of room in such a complicated and subtle chain for great variability.

The marked positive skewness of all the distributions has been commented upon sufficiently already.

VI

The distributions of Appendix Table 21 from age 20 on through age 69 have been fitted with Pearsonian skew frequency curves. This was a difficult and troublesome job of curve-fitting, because of the relative meagerness of the data, taking into account the great variation shown by all the distributions. It was necessary to make a preliminary smoothing of the raw data, and all monthly frequencies greater than 65 were omitted from the computations.

Under these restrictions the curves all proved to be of Pearson's Type III, of which the theoretical equation is as follows:

$$y = y_o e^{-p\frac{x}{a}}\left(1 + \frac{x}{a}\right)^{p} \tag{lii}$$

The equations of the fitted curves are:

$$\text{Age group 20–29:}\quad y = 69.92\, e^{-.5558x}\left(1 + \frac{x}{0.4796}\right)^{.2666} \tag{liii}$$

$$\text{Age group 30–39:}\quad y = 81.65\, e^{-.7133x}\left(1 + \frac{x}{0.7709}\right)^{.5499} \tag{liv}$$

$$\text{Age group 40–49:}\quad y = 83.24\, e^{-.9132x}\left(1 + \frac{x}{1.1185}\right)^{1.0215} \tag{lv}$$

$$\text{Age group 50–59;}\quad y = 115.17\, e^{-.9601x}\left(1 + \frac{x}{0.5403}\right)^{.4842} \tag{lvi}$$

$$\text{Age group 60–69:}\quad y = 160.90\, e^{-1.4136x}\left(1 + \frac{x}{0.1823}\right)^{.2577} \tag{lvii}$$

The observed histograms and fitted curves are shown graphically in Figs. 36–40 inclusive.

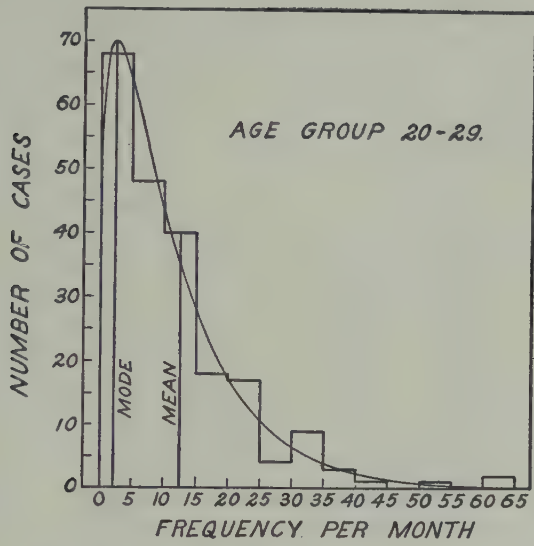

FIG. 36. Observed histograms and fitted curve showing the variation in sex activity (frequency per month) in the age period 20–29. This and the four following figures are all reduced to the same scale.

It is evident that the curves are about as satisfactory graduations as could be expected, considering the extreme range of variation exhibited in such a relatively small number of cases. It should be remembered in judging the quality of fit of these curves, especially those shown in Figs. 39 and 40, that it is the *area* under the curve over a unit range on the base line which is properly to be compared with the area of the histogram over the same base unit. A comparison of ordinates alone may be very misleading.

The striking things which seem to me to be brought out by these curves are these: First, the great rarity of the "sexual

athlete " type of individual, and second the rather extremely modest performance at all ages of the great bulk of the individuals in this group of 257 married men. There is a good deal that might be said about the psychological and sociolog-

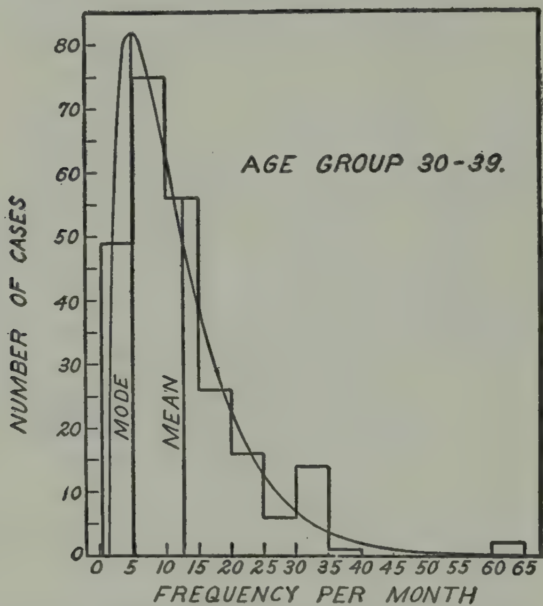

FIG. 37. Like Fig. 36, but for the age period 30–39.

ical implications of these results in relation to sex behavior, the problems of marriage and divorce, etc., but it is outside my present purpose to enter upon a discussion of these matters.

VII

We come now to the consideration of the specific reason for the introduction here of these data on sex behavior, which have been discussed in general terms up to this point.

In the preceding chapter it was suggested that relative wealth means to its possessors not merely better food, housing, etc., but also more avenues and opportunities for recreation, more varied intellectual interests, and generally wider outlets for nervous energy. It was further suggested that all

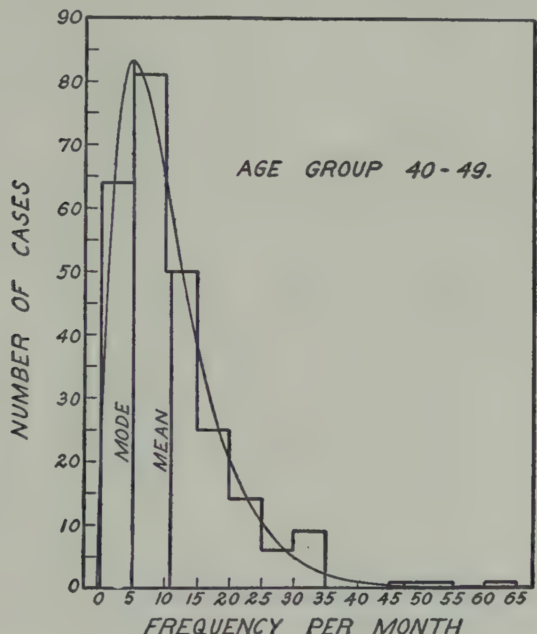

FIG. 38. Like Fig. 36, but for the age period 40–49.

of these things would tend towards less frequent sex activity and a lower birth rate. The other economic extreme of relative poverty would give the opposite picture. Poverty correlates not only with poor food and housing, but also with restricted opportunities for recreation, narrow intellectual interests, and generally only two reliable outlets for the speedy and satisfactory relief of nervous tension, of which one, and

perhaps the more important one, is the sexual relation. This situation, it was suggested, would correlate with more frequent sexual activity and a higher birth rate.

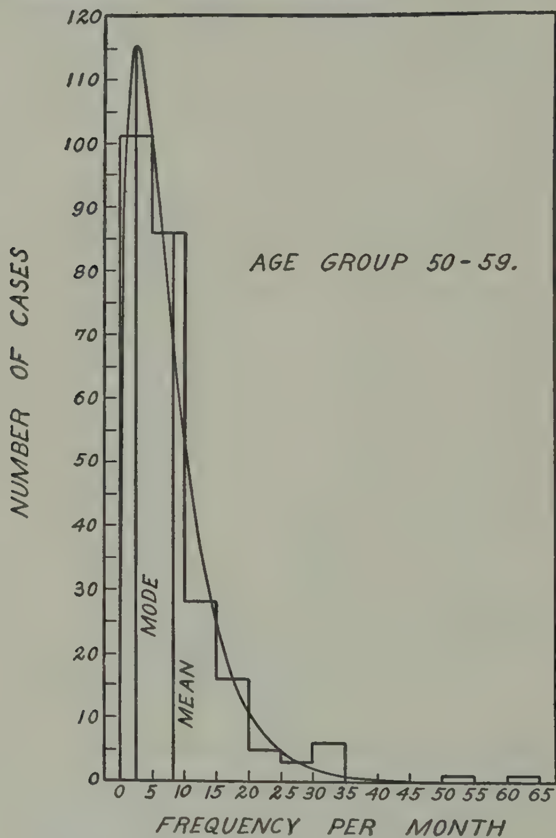

FIG. 39. Like Fig. 36, but for the age period 50–59.

Is there specific and positive, as distinguished from general and inferential, evidence that this view of the case is in fact correct? The present material furnishes just such evidence, I think. For most of the individuals in the group data exist

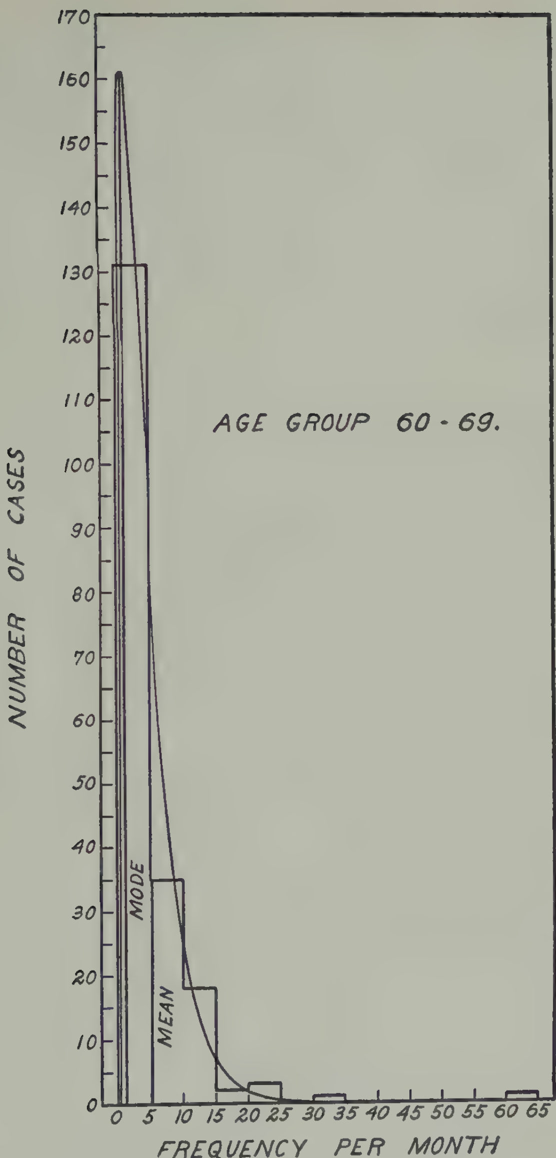

FIG. 40. Like Fig. 36, but for the age period 60–69.

in the records as to occupation and economic status. The material can therefore be separated into occupational groups, which will be generally indicative of social and economic status together. Table XXII gives the average frequency of sexual activity per month, by decade of age, in three broad occupational groups, namely (a) farmers, (b) merchants and bankers, and (c) professional men, including physicians, teachers, lawyers, etc.

TABLE XXII

Average Frequency per Month by Decades of Age and by Occupation

Age	Mean number of times per month					
	A. Farmers		*B.* Merchants and bankers		*C.* Professional men	
	N	Mean	*N*	Mean	*N*	Mean
15–19	14	8.9 ± 1.8	31	$5.6 \pm .8$	46	$4.2 \pm .5$
20–29	29	15.4 ± 1.6	56	12.9 ± 1.5	54	$9.7 \pm .9$
30–39	37	14.8 ± 1.3	65	13.7 ± 1.2	68	$11.8 \pm .8$
40–49	39	13.7 ± 1.3	67	$11.5 \pm .8$	68	$10.1 \pm .7$
50–59	39	11.1 ± 1.3	66	$8.7 \pm .7$	64	$7.0 \pm .5$
60–69	28	7.1 ± 1.4	49	$6.4 \pm .6$	53	$4.4 \pm .4$

The data of Table XXII are shown graphically in Fig. 41. In this table the columns headed *N* denote the number of cases on which the corresponding mean was based. It should be explained that the total number of persons in the farmer group (column A) for example, was 39, but 15 of them were unable to furnish information on the point for the age period 15–19; 10 were unable to furnish information for the age period 20–29, and so on.

What Table XXII and Fig. 41 show is that in the group of farmers, where the economic status was lowest, the intellec-

tual content of life the least varied and interesting, and the outlets for nervous and emotional tension most restricted, the average frequency was highest at all periods of life. In

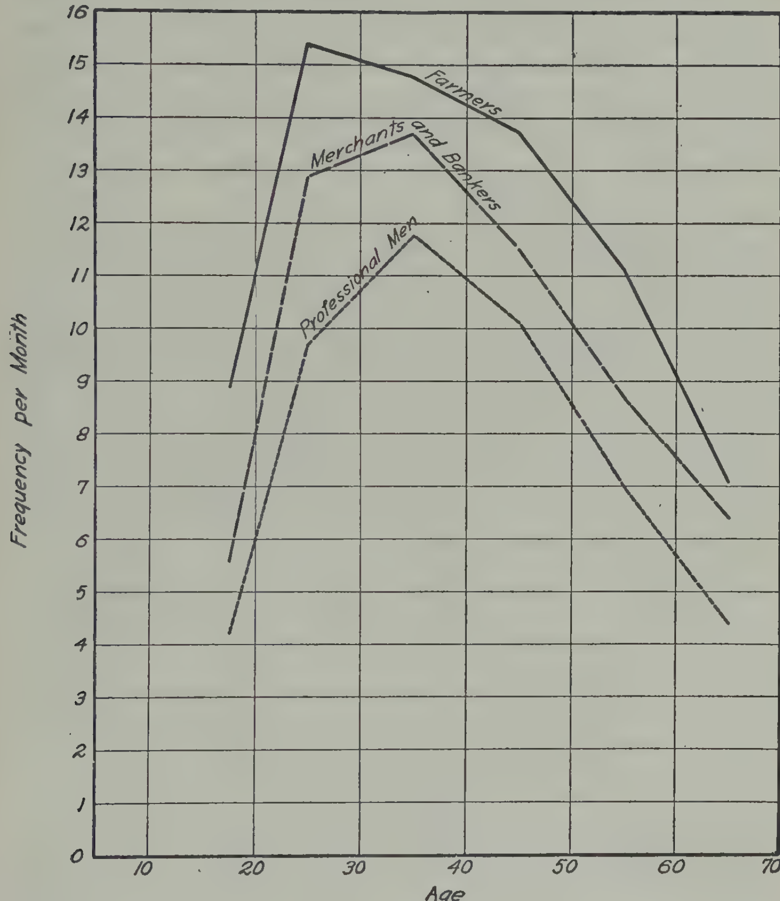

FIG. 41. The average monthly frequency of sexual activity in different occupational groups. Solid line denotes farmers; dash line — merchants and bankers; dot line — professional men.

the professional group where the economic status was (in this particular material) high, the intellectual content of life most varied and interesting, and the pleasant and satisfactory outlets for nervous energy most manifold, the average frequency of sexual activity was lowest. The merchant and the banker group was intermediate to the other two groups in all these respects save economic status, where the level was about the same as in the professional group.

VIII

The question next arises as to whether the birth rate follows the sexual activity rate in its variation among social and economic groups. In general it would seem probable that it does. But I have no desire to generalize on this point at this time. It will be recalled that a warning was given at the beginning of this chapter against drawing too general conclusions from the present series. And the only statistical data of any magnitude at all that I know of on the sexual activity rate are those presented in this chapter.

For a part of each of the groups of Table XXII we have data on the size of completed family, that is the total fertility of married life. The results are as follows:

Group	Number of completed families	Mean number of children
Farmers	12	4.7
Merchants and bankers	19	2.5
Professional	17	2.3

These data, which if not so extensive statistically as one would like, are of a high order of accuracy, are directly and specifically pertinent to the point at issue, and finally are, so far as the sex activity aspect is concerned, much more exten-

sive than anything which has hitherto been available, seem clearly to support the argument which I have made.

It is very difficult to determine from general official statistics anything about the birth rate of the general population in the several different occupational groups that we have been discussing. Cities usually show a higher crude birth rate than rural areas, but this presumably only means that the age distribution of the female population in cities is much more favorable to child bearing than is that of rural women. We must in this case, as in most others in my experience when we want to penetrate to any depth in a problem of human biology, have recourse to specially collected *ad hoc* material. Happily for the present need I have in the archives of the laboratory a large number of family records extracted from certain well-known genealogies (152–156 inclusive). From this material have been sorted out for the present purpose all married males. These cards were then sorted relative to the occupations of the individuals. For presentation here the following four occupational groups were chosen:

Farmers,

Merchants,

Teachers and college professors,

Professional men, including lawyers, judges, physicians, senators and congressmen, dentists, etc.

Then from the cards in each occupational group was made a frequency distribution relative to size of family, that is total progeny of which the individual was the father. The results are shown in Table XXIII. It should be clearly understood that the data do not represent the fertility of the individual wives of these men, because some of the men married more than once. The great bulk of them did not, however, so that the figures in Table XXIII are probably only a fraction of a child per family larger than they would be if

TABLE XXIII

THE SIZE OF COMPLETED FAMILIES (TOTAL PROGENY) BY OCCUPATIONAL GROUPS

Total progeny from completed marriages	Farmers	Merchants	Teachers and college professors	Professional
0	78	35	6	14
1	88	28	..	25
2	141	33	5	35
3	187	37	10	33
4	192	36	7	17
5	184	32	3	29
6	184	22	6	24
7	148	15	3	14
8	147	22	5	8
9	141	20	3	8
10	113	17	4	17
11	76	9	..	2
12	44	4	1	4
13	29	2	..	2
14	9	..	..	1
15	6	2	..	2
16	5	1	..	..
17	4	1	..	..
18	...	..	..	..
19	...	1	..	..
20	...	..	..	..
21	1	..	..	..
22	...	..	..	..
23	1	..	..	..
Totals	1770	317	53	235

FROM TABLE XXIII ARE DERIVED THE FOLLOWING AVERAGES

Occupational group	Mean total progeny per father
Farmers	$5.92 \pm .06$
Teachers	$4.89 \pm .28$
Merchants	$4.82 \pm .14$
Professional	$4.66 \pm .15$

only the once married males had been included. But what I wanted to get at in the present connection was the total sex

activity of these men as reflected in their total progeny. Since all the men included were dead at the time of record their complete reproductive activity is reflected in these figures. One other word of cautionary explanation is needed. The data being derived from genealogical records extend well over a century into the past, and the progeny figures are consequently larger than they would be for the same occupations in the present day of a greatly fallen birth rate. But there is no particular reason to suppose that the motivating forces leading to a differential birth rate in respect of occupation have greatly altered. I think we may regard the groups as comparable *inter se* on substantially the same basis that they would be today.

This genealogical material includes few really rich people in any of the groups. The differences between the means for teacher, merchant and professional groups are not significant statistically, but the classes are, for this material considering its time, in about the right order of ascending wealth and varied intellectual, aesthetic and emotional resources. The difference between the farmer and professional groups is approximately eight times its probable error.

These results unequivocally support those from the more meager data discussed previously, and together with them lead to the conclusion that the argument set forth in this and the preceding chapter as to the psychological and social factors lying behind the observed negative correlation between birth-rate and wealth is at least in some degree sound.

CHAPTER IX

SUMMARY AND CONCLUSIONS

In this book I have presented evidence which seems to me to show the following things:

First, that populations grow in size according to the same mathematical law that individual animals and plants follow in the growth of their bodies in size. This can be, and has been demonstrated experimentally for populations of such relatively simple creatures as the yeast plant and the fruit fly, *Drosophila melanogaster*.

Second, that human populations grow according to the same law as do the experimental populations of lower organisms, and in turn as do individual plants and animals in body size. This is demonstrated in two ways: first, by showing as was done in my former book "Studies in Human Biology," that in a great variety of countries all of the recorded census history which exists is accurately described by the same general mathematical equation as that which describes the growth of experimental populations; second, by bringing forward in the present book the case of a human population — the indigenous native population of Algeria — which has in the 75 years of its recorded census history practically completed a single cycle of growth along the logistic curve.

Third, that in the case of this native population of Algeria the trends, both of the birth rate, which is unaffected by the practice of contraception (birth control), and of the death rate, which on the evidence cannot have been significantly affected by the practice of public health measures, have been

in recent years what would be expected on the mathematical theory of the logistic law of population growth, considering the position of this population on its curve at the time, and other relevant circumstances.

At this point it was argued that the results indicated that one of the most important problems in connection with population for future research, was that of the biological causes influencing the shape of the logistic curve.

To this problem the latter half of the book is addressed, and it is therein shown:

Fourth, that rate of reproduction or fertility is negatively correlated with density of population, in (a) experimental populations of flies, (b) experimental populations of hens, and (c) urban populations of human beings. This array of evidence indicates that in the direct and indirect biological effects of density of population upon reproduction exists one *vera causa* for the damping off of the growth of population as the upper limit of the logistic curve is approached.

Fifth, that birth rate is negatively correlated with wealth (or positively correlated with poverty), and that the differential birth rate on this economic base constitutes one of the menacing features of human population growth, which, however, can possibly be met in some part by an entirely free dissemination of knowledge about birth control.

Sixth, that the indirect psychological and social effects of relative poverty as contrasted with relative wealth express themselves definitely and clearly in the sexual activity of human beings, and through sexual activity to birth rates.

So much for the evidence. It represents the results of an honest, painstaking, and vastly more laborious than is apparent, piece of scientific investigation. Now that it is done, my own principal interest in it is that it suggests at many points further lines of research to be attacked. But I cannot

close the present record without making a few remarks about some of the general humanistic implications of the present state of research upon the population problem. They are only opinions, which I cannot prove, but perhaps my labors on the purely objective aspects of the matter will be thought to bestow the right to a few paragraphs of mere opinion.

Should the somewhat inexorable advance in the number of people on this globe which the biological law of population growth makes extremely probable, lead us to view-with-alarm? It seems to me that if we so conclude, we ought equally to be concerned about the orderly growth of any baby into manhood or womanhood. For I am quite firmly convinced that the biological inevitability of the one form of growth is not greater than that of the other. The human population of the world is going on increasing for a long time to come, and perhaps at times at an even more rapid rate than the present one. As old Malthus said " the passion between the sexes is necessary, and will remain nearly in its present state." Furthermore, continued improvement in sanitation and in knowledge of preventive medicine and hygiene is going to add to the population existing at any given moment as surely as an increased birth rate would.

Will this process necessarily increase the sum total of human misery and wretchedness in the world, as we are told it will? I used to think so, but the longer I have pondered over the matter the less sure I feel about this conclusion. I think the thing which first made me dubious about this inevitable misery doctrine was its seemingly compelling logic. It was so easy to prove logically that it must be so that I began to be suspicious that in fact it probably was not so at all. Long experience with experimental work has taught me that a somewhat rough and ready, but on the whole dependable, rule is that any natural phenomenon which, in advance of observation of

the event, can be proved by purely logical processes to be necessarily so, almost invariably turns out upon really competent and penetrating trial or observation to be in fact not so at all but quite otherwise. This curious phenomenon is, of course, not the fault of logical processes of thought, but merely an expression of human fallibility in the matter of premises.

That population pressure will in the future, as it has in the past, lead to wars, seems to me to be, unfortunately, in the highest degree probable, at least for a long time to come. But the contention that growth of population must inevitably increase the general wretchedness of human life apart from wars seems to me to overlook three important facts. As one studies the curves of population growth for various countries, and particularly that for the world as a whole, he is bound to be struck by the thought that while we have gone a long way in the present cycle of growth there has not been, in fact, any such marked increase in squalor, wretchedness and general unhappiness associated with increase in population over what existed before in the same group of people, as we are accustomed somewhat loosely to predicate. Even allowing for the misery entailed by the Great War it is surely true that at no previous time in the recorded history of mankind was so large a proportion of the population on the whole so happy, and so socially and humanly well off, as they are right now. France, for example, is a country with a population near the maximum for the present cycle. But he who thinks France an unhappy or wretched country is both ignorant and stupid.

The reason why, in general, great misery has not been associated with population growth appears to me to flow out of the other two more or less overlooked considerations to which I have referred. The first of these is the definite and rather

orderly evolution of human knowledge; especially of natural processes and of how to control and use them to the benefit of mankind. To put a nearby final limit on scientific discovery of ways and means of expanding the opportunities of happy human subsistence would seem to be a highly rash proceeding, in the face of what has happened in the last century even. Haldane's "Daedalus" I should think probably not more daring in this day than Jules Verne's "Twenty Thousand Leagues" was in its. It must be remembered that applied biology is in its veriest infancy, as compared with applied chemistry, for example. And one hears no note of pessimism from the chemists.

Finally, and as it seems to me most important of all, have we not overlooked to a large degree in our discussion of the population problem, the largely unknown and unplumbed adaptive potentialities of the human organism? Is not adaptation the crux of the whole matter within rather wide limits? Some years ago it would have been possible, by precisely the same kind of logic that leads to the inevitable misery conclusion regarding the population problem, to prove that it would be impossible for civilized human beings to live happily in Nome, Alaska, or for a thriving city of happy and contented people to spring up where Edmonton now is just that. Perhaps the most important of all biological phenomena, adaptation is the least understood. We can only dimly envisage a small fraction of the changes in the mode of human existence which population pressure will entail.

But that these responses to environmental forces will be generally adaptive seems to me certain. They will somehow or other conduce to well-being and happiness. Birth control would seem to be a case in point. It is an intelligent adaptive response to an environmental force, population pressure. It is an attempt to slow the rate of population growth and

thereby maintain the level of living standards. It will become more and more wide-spread. But it is only one of the many ways by which mankind will succeed in adapting itself to the situation created by the biological law of population growth. Another is public health and hygiene. Under the conditions of sanitation and hygiene which prevailed even a hundred years ago, nothing like our present urban population densities would have been possible. Public health measures both absolutely increase population and also the environmental conditions which make larger populations possible. They increase the happiness and well-being of the component elements of population. Such measures are, in short, adaptive responses of the human species to population pressure.

APPENDIX OF TABULAR DATA

TABLE 1

Observed and Calculated Values for the Growth in Weight of the Male White Rat. (Donaldson's Data)

(This table is discussed on p. 6)

Age in days	Observed weight in grams	Calculated weight by equation (i)	Age in days	Observed weight in grams	Calculated weight by equation (i)
10	13.5	14.1	70	106.3	103.8
11	13.3	14.5	73	113.8	110.7
12	14.8	15.0	76	121.3	117.6
13	15.3	15.5	79	128.2	124.3
14	15.2	16.1	82	135.0	130.9
15	16.5	16.7	85	143.8	137.4
17	17.8	17.9	88	148.4	143.7
19	19.5	19.3	92	152.3	151.7
21	21.2	20.8	97	160.0	161.2
23	22.9	22.4	102	168.8	170.0
25	25.3	24.2	107	177.6	178.1
27	27.4	26.1	112	183.8	185.5
29	29.5	28.2	117	191.4	192.2
31	31.8	30.5	124	197.3	200.6
34	34.9	33.2	131	202.5	208.1
37	37.8	38.3	138	209.7	214.5
40	42.2	42.7	143	218.3	218.6
43	46.3	48.6	150	225.4	223.7
46	50.5	52.8	157	227.0	228.2
49	56.7	58.3	164	231.4	232.1
52	62.5	64.2	171	235.8	235.7
55	68.5	70.4	178	239.4	238.9
58	73.9	76.8	185	239.8	241.9
61	81.7	83.4	216	252.9	252.7
64	89.1	90.1	256	265.4	264.4
67	99.3	97.0	365	279.0	279.6
			Root mean square deviation	.....	4.96

TABLE 2

Growth of Cucurbita Pepo. (Data from Robertson)

(This table is discussed on p. 7)

Days	Observed weight in grams	Calculated weight by equation (ii)	Days	Observed weight in grams	Calculated weight by equation (ii)
5	267	267	16	4720	4680
6	443	399	17	4864	4850
7	658	645	18	4980	4984
8	961	1044	19	5114	5089
9	1498	1586	20	5176	5172
10	2200	2210	21	5242	5236
11	2920	2829	22	5298	5282
12	3366	3378	23	5352	5315
13	3758	3829	24	5360	5337
14	4092	4186	25	5366	5350
15	4488	4464	Root mean square deviation	....	46.1

TABLE 3

REGENERATION OF TADPOLE TAIL. (DURBIN'S DATA)

(This table is discussed on p. 8)

Days	Observed regeneration in mm.	Calculated regeneration from equation (iii)	Days	Observed regeneration in mm.	Calculated regeneration from equation (iii)
0	....	0.11	13	....	6.37
1	....	0.22	14	6.60	6.71
2	....	0.40	15	....	7.00
3	0.68	0.68	17	7.60	7.48
4	....	1.09	19	....	7.88
5	....	1.62	23	....	8.58
6	....	2.25	27	....	9.17
7	2.95	2.95	29	9.68	9.38
8	....	3.66	31	....	9.50
9	....	4.34	33	9.20	9.57
10	5.00	4.96	37	9.30	9.60
11	....	5.50	41	9.60	9.60
12	....	5.97	51	9.40	9.60
			Root mean square deviation	....	0.196

TABLE 4

THE GROWTH OF A POPULATION OF YEAST CELLS. (CARLSON'S DATA)

(This table is discussed on p. 9)

Days of Growth	Quantity of yeast		Days of Growth	Quantity of yeast	
	Observed	Calculated		Observed	Calculated
0	9.6	9.9	10	513.3	506.9
1	18.3	16.8	11	559.7	562.3
2	29.0	28.2	12	594.8	600.8
3	47.2	46.7	13	629.4	625.8
4	71.1	76.0	14	640.8	641.5
5	119.1	120.1	15	651.1	651.0
6	174.6	181.9	16	655.9	656.7
7	257.3	260.3	17	659.6	660.1
8	350.7	348.2	18	661.8	662.1
9	441.0	433.9	Root mean square deviation		3.59

TABLE 5

The Population Growth of Sweden

(This table is discussed on p. 11)

Year	Population in millions		Year	Population in millions	
	Calculated	Observed		Calculated	Observed
Lower asympt.	1.535	.....	1870	4.119	4.168
1700	1.621	.....	1880	4.477	4.566
1720	1.670	.....	1890	4.841	4.785
1740	1.747	.....	1900	5.202	5.136
1750	1.800	1.763	1910	5.549	5.522
1760	1.864	1.893	1920	5.876	5.904
1770	1.944	2.030	1940	6.446	.....
1780	2.041	2.118	1960	6.890	.....
1790	2.160	2.158	1980	7.215	.....
1800	2.302	2.347	2000	7.440	.....
1810	2.471	2.378	2020	7.592	.....
1820	2.669	2.585	2040	7.692	.....
1830	2.900	2.888	2060	7.757	.....
1840	3.162	3.139	2080	7.798	.....
1850	3.455	3.483	2100	7.825	.....
1860	3.776	3.800	Upper asympt.	7.871	.....

TABLE 6

THE POPULATION GROWTH OF THE UNITED STATES*

(This table is discussed on p. 13)

Year	Population in millions		Year	Population in millions	
	Calculated	Observed		Calculated	Observed
Lower asympt.	0.000	.....	1900	76.870	75.995
1700	0.239	.....	1910	91.972	91.972
1720	0.446	.....	1920	107.394	......
1740	0.833	.....	1930	122.397	......
1760	1.553	.....	1940	136.318	......
1780	2.887	.....	1950	148.678	......
1790	3.929	3.929	1960	159.230	.....
1800	5.336	5.308	1970	167.945	......
1810	7.228	7.240	1980	174.941	......
1820	9.757	9.638	1990	180.437	......
1830	13.109	12.866	2000	184.678	......
1840	17.506	17.069	2020	190.341	......
1850	23.192	23.192	2040	193.509	......
1860	30.412	31.443	2060	195.249	......
1870	39.372	38.558	2080	196.337	......
1880	50.177	50.156	2100	196.681	......
1890	62.769	62.948	Upper asympt.	197.274	......

*Data from Statistical Abstract

TABLE 7

THE POPULATION GROWTH OF FRANCE *

(This table is discussed on p. 15)

Year	Population in millions		Year	Population in millions	
	Calculated	Observed		Calculated	Observed
Lower asympt.	6.604	......	1872	36.709	36.103
1500	6.723	......	1876	37.087	36.906
1550	6.921	......	1881	37.531	37.672
1600	7.442	......	1886	37.944	38.219
1650	8.768	.....	1891	38.328	38.343
1700	11.877	......	1896	38.685	38.518
1720	13.912	......	1901	39.015	38.962
1740	16.480	......	1906	39.319	39.252
1760	19.543	......	1911	39.600	39.602
1780	22.960	......	1920	40.051	......
1801	26.668	26.931	1940	40.836	......
1821	30.059	29.871	1960	41.386	......
1841	33.063	33.401	1980	41.766	......
1861	35.563	35.845	2000	42.027	......
1866	36.104	36.495	Upper asympt.	42.579	......

* Observed values taken from Statesman's Year Book.

TABLE 8

The Population Growth of Germany *

(This table is discussed on p. 20)

Year	Population in millions		Year	Population in millions	
	Calculated	Observed		Calculated	Observed
Lower asympt.	10.109	......	1861	32.281	38.140
1700	10.372	......	1871	40.867	41.059
1720	10.681	......	1880	44.230	45.230
1740	11.344	......	1890	49.430	49.430
1760	12.712	......	1900	56.370	56.367
1780	15.354	......	1910	64.930	64.930
1800	19.846	......	1920	74.518	......
1810	22.797	......	1930	84.165	......
1816	24.728	24.833	1940	92.876	......
1822	27.725	27.040	1950	100.009	......
1831	29.723	29.770	1960	105.394	......
1840	32.565	32.790	1970	109.218	......
1855	36.586	36.114	1980	111.815	......
			1990	113.526	......
			2000	114.632	......
			Upper asympt.	116.531	......

Curve I		Curve II	
Year	Population	Year	Population
1860	37.681	Lower asympt.	33.587
1870	39.499	1800	33.866
1880	40.867	1830	34.721
1890	41.863	1840	35.392
1900	42.572	1850	36.440
Upper asympt.	44.145		

* Observed figures are from Statesman's Year Book. Calculated figures come from two curves, one running to 1855 and the other from 1855 on.

TABLE 9

GROWTH OF WILD TYPE DROSOPHILA POPULATION IN HALF-PINT BOTTLES

(This table is discussed on p. 34)

Date of census	Population in bottle 1	Population in bottle 2	Average of bottles 1 and 2	Calculated population from equation (xi)
April 8	2	2	2	1.9
April 21	40	18	29	48.6
April 23	71	52	61.5	71.4
April 26	112	120	116	112.6
April 29	153	148	150.5	151.9
May 2	168	192	180	180.1
May 6	199	216	207.5	199.9
May 8	177	215	196	204.7
May 11	190	232	211	208.7
May 14	204	214	209	210.5

TABLE 10

GROWTH OF WILD TYPE DROSOPHILA POPULATION IN A PINT BOTTLE

(This table is discussed on p. 36)

Date of census	Observed population	Calculated population from equation (xii)
December 2	22	14.3
December 11	39	61.0
December 14	105	96.7
December 17	152	150.2
December 20	225	226.0
December 23	390	326.0
December 27	499	488.4
December 29	547	574.1
December 31	618	656.8
January 4	791	798.4
January 7	877	877.1
January 10	938	932.9

TABLE 11

GROWTH OF POPULATION OF QUINTUPLE STOCK OF DROSOPHILA IN A PINT BOTTLE

(This table is discussed on p. 39)

Date of census	Observed population	Calculated population from equation (xiii)
October 6	6	6.0
October 9	10	11.3
October 13	21	25.9
October 15	52	38.5
October 18	67	67.0
October 21	104	109.2
October 24	163	162.6
October 27	226	218.0
October 30	265	265.0
November 3	282	306.8
November 7	319	324.5

TABLE 12

Indigenous Native Population of Algeria

(This table is discussed on pp. 61–72)

Period	Census	Total observed indigenous native population A	Calculated native population from equation (xix) B
Of Subjugation	1856	2,307,349	2,355,000
	1861	2,723,851	2,402,000
	1866	2,652,072	2,482,000
	1872	2,125,052	2,595,000
	1876	2,462,936	2,753,000
	1881	2,842,497	2,962,000
Of Citizenship	1886	3,287,217	3,224,000
	1891	3,577,063	3,529,000
	1896	3,781,098	3,859,000
	1901	4,098,355	4,184,000
	1906	4,477,788	4,478,000
	1911	4,740,526	4,723,000
	1921	4,924,938	5,060,000

Lower asymptote = 2,238,000
Upper asymptote = 5,379,000

TABLE 13

COMPARING FITTED CURVES AND OBSERVATIONS FOR THE NATIVE POPULATION OF ALGERIA

(This table is discussed on pp. 56–72)

Year	Observed populations (From Appendix Table 12) A	Calculated populations from equation (xviii) B	Percentage deviations of calculated from observed values (Equation xviii) C	Calculated populations from equation (xix) D	Percentage deviations of calculated from observed values (Equation xix) E
1881	2,842,497	3,213,000	+ 11.55	2,962,000	+ 4.05
1886	3,287,217	3,318,000	+ .93	3,224,000	− 1.95
1891	3,577,063	3,507,000	− 2.00	3,529,000	− 1.36
1896	3,781,098	3,796,000	+ .39	3,859,000	+ 2.02
1901	4,098,355	4,148,000	+ 1.21	4,184,000	+ 2.06
1906	4,477,788	4,476,000	− .04	4,478,000	± 0
1911	4,740,526	4,712,000	− .62	4,723,000	− 0.38
1921	4,924,938	4,929,000	+ .08	5,060,000	+ 2.67

TABLE 14

CRUDE DEATH RATES OF (*a*) EUROPEAN, (*b*) NATIVE POPULATION OF ALGERIA, 1901–1914; AND OF (*c*) FRANCE; (*d*) U.S. REGISTRATION AREA; (*e*) ENGLAND AND WALES

(This table is discussed on pp. 81–83)

Year	Death rate per 10,000 inhabitants of				
	European population of Algeria	Mohammedan population of Algeria	France	U.S. Registration Area	England and Wales
1901	223	245	201	165	169
1902	218	199	195	159	163
1903	185	184	192	160	155
1904	234	278	194	165	163
1905	210	239	196	160	153
1906	196	214	199	157	155
1907	196	218	202	160	151
1908	188	202	189	148	148
1909	190	219	191	144	146
1910	180	211	178	150	135
1911	177	207	196	142	146
1912	161	178	175	139	133
1913	171	177	177	141	138
1914	166	192	196	136	140

TABLE 15

Public Education in Algeria

(This table is discussed on p. 86)

Class of school and nationality	Number of students in indicated years					
	1915–16	1916–17	1917–18	1918–19	1919–20	1920–21
A. Primary Education						
1. Écoles primaires et maternelles						
a. French	80,486	81,469	82,529	71,872	73,977	71,296
b. Israelites	18,862	19,081	15,411	16,848	14,484	15,633
c. Mussulmans	44,026	42,758	39,317	42,353	41,144	42,904
d. Foreign	39,095	31,915	31,010	28,391	26,847	25,294
2. Écoles normales						
a. French	276	273	293	343	338	328
b. Israelites	21	15	18	14	28	19
c. Mussulmans	55	29	41	53	55	51
d. Foreign	...	...	...	...	...	...
B. Secondary Education						
1. Établissements publiques						
a. French	5,528	5,684	6,110	6,685	6,970	6,598
b. Israelites	1,078	1,243	1,358	1,528	1,867	1,925
c. Mussulmans	422	470	445	464	477	434
d. Foreign	142	193	201	158	163	170
2. Établissements libres						
a. French	648	690	606	1,014	754	784
b. Israelites	64	32	5	1	...	4
c. Mussulmans	2	3	6	15	23	24
d. Foreign	104	126	167	47	41	14
Total (*A* and *B*)						
a. French	86,738	88,116	89,538	74,757	82,039	79,006
b. Israelites	20,025	20,371	16,792	18,391	16,379	17,581
c. Mussulmans	44,505	43,260	39,809	42,885	41,699	43,413
d. Foreign	39,341	32,234	31,378	28,596	27,051	25,478
C. Higher Education (University of Algiers)						
a. French	768	334	767	836	1,483	1,467
b. Indigènes	39	61	61	41	17	47
c. Foreign	24	84	88	75	51	27

TABLE 16

Deaths per 10,000 Inhabitants at Each Age. Territoires du Nord. Average of Years 1911–1913 (Bunle)

(This table is discussed on p. 98)

Age	Europeans		Mussulmans		United States Registration Area	
	Males	Females	Males	Females	Males	Females
Under 1	1516	1330	2113	1686	1249.5	1037.7
1– 4	372	242	317	272	80.7	75.9
5– 9	39	41	67	66	34.5	31.4
10–14	28	27	57	66	23.5	21.0
15–19	45	37	79	81	36.5	33.9
20–24	97	59	107	99	55.4	48.5
25–29	79	76	151	140	60.0	56.9
30–39	97	74	164	141	87.4	73.0
40–49	155	92	200	147	128.4	101.2
50–59	282	149	288	201	217.8	182.0
60–69	504	354	510	430	440.6	381.5
70–79	1010	907	450	433	927.2	825.5
80–89	1950	1635	688	723	1909.4	1780.7
90–99	2548	4102	1050	976	3217.6	3282.8
100 and over	4167	4000	2080	2570	4280.9	4101.9

TABLE 17

LIVING BIRTHS PER 10,000 INHABITANTS. TERRITOIRES DU NORD.

(This table is discussed on pp. 105, 116–119)

Year	European population	Mohammedan population
1901	297	273
1902	311	312
1903	306	328
1904	302	323
1905	282	295
1906	298	280
1907	289	280
1908	314	303
1909	295	279
1910	313	294
1911	273	290
1912	288	309
1913	293	293
1914	283	261

TABLE 18

Birth Rates per 10,000 Population of Various Countries 1900–1913 Inclusive. (Knibbs's Data)

(This table is discussed on pp. 117–119)

Year	England and Wales	France	Netherlands	Denmark
1900	287	214	316	297
1901	285	220	323	297
1902	285	217	318	292
1903	285	211	316	287
1904	280	209	314	289
1905	273	206	308	284
1906	272	206	304	285
1907	265	197	300	282
1908	267	201	297	285
1909	258	195	291	282
1910	251	196	286	275
1911	244	187	278	267
1912	238	190	281	267
1913	239	190	281	256

TABLE 19

DATA FOR CITIES USED IN PARTIAL CORRELATION STUDY

(This table is discussed on pp. 150–156)

City	Birth rate B	Density A	Population P	Wealth W	School attendance 18–20 S	House density D
Berkeley, Cal.	121.6	10.3	56,036	$1,296.16	47.7	4.3
Fresno, Cal.	179.9	8.8	45,086	1,003.70	20.3	4.7
Los Angeles, Cal.	128.2	2.4	576,673	1,844.82	20.9	4.6
Oakland, Cal.	121.5	6.6	216,261	1,456.34	22.3	4.6
Pasadena, Cal.	141.6	4.5	45,354	2,147.11	34.7	3.9
Sacramento, Cal.	158.9	7.3	65,908	1,595.43	18.7	4.8
San Diego, Cal.	154.4	1.4	74,683	1,385.05	22.9	4.0
San Francisco, Cal.	122.7	18.6	506,676	2,253.69	21.8	5.6
San Jose, Cal.	135.2	7.8	39,642	1,142.02	31.0	4.2
Stockton, Cal.	158.6	7.6	40,296	1,560.62	17.0	4.8
Bridgeport, Conn.	188.1	14.7	143,555	1,592.05	8.4	6.4
Hartford, Conn.	210.6	13.1	138,036	1,267.60	13.9	8.4
New Britain, Conn.	206.0	6.9	59,316	872.64	11.3	9.7
New Haven, Conn.	189.1	13.8	162,537	1,164.65	13.0	7.2
Stamford, Conn.	199.0	7.5	35,096	1,213.24	12.5	7.5
Waterbury, Conn.	198.0	4.9	91,715	1,272.47	12.0	7.9
East Chicago, Ind.	204.2	5.2	35,967	2,196.39	5.6	7.1
Evansville, Ind.	114.7	14.9	85,264	906.46	8.9	4.5
Fort Wayne, Ind.	136.3	11.6	86,549	1,343.11	11.7	4.6
Gary, Ind.	173.7	2.5	55,378	1,541.42	7.4	6.7
South Bend, Ind.	166.9	7.0	70,983	1,283.90	9.3	4.9
Terre Haute, Ind.	133.5	12.0	66,083	1,052.10	18.0	4.3
Topeka, Kans.	151.3	4.9	50,022	1,602.50	18.6	4.2
Wichita, Kans.	139.1	5.5	72,217	1,136.57	20.2	4.6
Covington, Ky.	147.3	14.8	57,121	759.73	11.9	5.1
Newport, Ky.	130.5	38.0	29,317	716.86	9.6	5.2
Portland, Maine	169.7	4.9	69,272	1,459.28	22.3	6.3
Boston, Mass.	207.8	26.5	748,060	2,004.30	15.2	9.4
Brockton, Mass.	164.9	4.7	66,254	831.17	16.4	6.4
Brookline, Mass.	64.4	8.4	37,748	2,586.13	42.1	7.5
Cambridge, Mass.	207.3	27.1	109,694	1,235.71	18.5	7.3
Chelsea, Mass.	218.1	33.0	43,184	832.80	12.5	9.8
Everett, Mass.	161.1	18.8	40,120	999.22	15.4	5.8
Fall River, Mass.	235.7	5.5	120,485	1,070.82	11.3	8.7

TABLE 19 (Continued)

DATA FOR CITIES USED IN PARTIAL CORRELATION STUDY

(This table is discussed on pp. 150–156)

City	Birth rate *B*	Density *A*	Population *P*	Wealth *W*	School attendance 18–20 *S*	House density *D*
Fitchburg, Mass.	202.1	2.3	41,029	$1,054.42	12.7	6.6
Haverhill, Mass.	164.2	2.6	53,884	900.46	12.0	5.9
Holyoke, Mass.	208.6	4.5	60,203	1,177.99	16.9	10.6
Lawrence, Mass.	193.2	22.2	94,270	968.42	11.3	7.4
Lowell, Mass.	219.9	13.4	112,759	887.16	14.3	6.4
Lynn, Mass.	147.8	14.1	99,148	1,000.71	14.3	6.7
Malden, Mass.	178.8	15.8	49,103	836.93	19.2	5.8
New Bedford, Mass.	201.0	9.6	121,217	1,111.77	9.4	8.1
Newton, Mass.	165.0	4.1	46,054	1,666.10	32.8	5.1
Pittsfield, Mass.	191.7	1.5	41,763	1,027.53	11.6	5.4
Quincy, Mass.	150.8	4.2	47,876	1,070.34	17.5	5.0
Salem, Mass.	218.2	8.3	42,529	997.57	14.5	7.2
Somerville, Mass.	149.6	34.8	93,091	933.60	19.5	6.2
Springfield, Mass.	177.2	6.0	129,614	1,640.30	16.7	6.8
Taunton, Mass.	206.6	1.3	37,137	749.87	15.6	6.2
Waltham, Mass.	211.4	3.8	30,915	1,043.44	17.5	5.4
Worcester, Mass.	200.3	7.3	179,754	1,139.01	15.3	9.3
Battle Creek, Mich.	126.2	9.5	36,164	1,629.88	16.4	4.4
Bay City, Mich.	190.6	7.5	47,554	631.15	12.6	4.5
Detroit, Mich.	166.5	18.9	993,678	1,459.83	8.1	6.5
Flint, Mich.	189.5	4.6	91,599	797.03	6.0	5.6
Grand Rapids, Mich.	154.3	11.9	137,634	1,340.06	13.8	4.7
Highland Park, Mich.	102.1	22.8	46,499	3,166.65	12.6	5.8
Jackson, Mich.	155.0	8.1	48,374	958.44	10.6	4.6
Kalamazoo, Mich.	177.2	9.0	48,487	1,093.52	15.4	4.6
Lansing, Mich.	154.9	7.8	57,327	906.11	12.8	4.7
Saginaw, Mich.	181.0	6.9	61,903	877.04	9.3	4.4
Duluth, Minn.	174.2	2.5	98,917	2,228.69	13.7	5.7
Minneapolis, Minn.	161.4	11.6	380,582	1,839.37	20.6	5.8
St. Paul, Minn.	155.4	6.9	234,698	1,802.52	15.7	5.5
Lincoln, Neb.	164.5	7.8	54,948	1,324.65	30.0	4.5
Omaha, Neb.	152.3	7.9	191,601	1,628.40	14.2	5.0
Manchester, N.H.	212.3	3.7	78,384	1,080.70	15.7	7.4
Albany, N.Y.	152.7	9.4	113,344	1,131.11	15.9	6.2

TABLE 19 (Continued)

DATA FOR CITIES USED IN PARTIAL CORRELATION STUDY

(This table is discussed on pp. 150–156)

City	Birth rate *B*	Density *A*	Population *P*	Wealth *W*	School attendance 18–20 *S*	House density *D*
Amsterdam, N.Y.	171.5	9.5	33,524	$ 675.67	7.8	6.7
Auburn, N.Y.	155.3	6.7	36,192	877.64	14.3	5.0
Binghamton, N.Y.	168.2	10.8	66,800	847.01	13.1	6.4
Buffalo, N.Y.	181.6	20.0	506,775	1,125.99	11.4	6.9
Elmira, N.Y.	180.4	9.7	45,393	859.39	29.0	4.9
Jamestown, N.Y.	143.8	7.0	38,917	1,200.80	15.2	4.9
Mount Vernon, N.Y.	159.2	15.6	42,726	1,286.28	19.0	7.3
New Rochelle, N.Y.	129.5	5.5	36,213	2,122.60	14.8	6.6
New York, N.Y.	161.4	28.7	5,620,048	1,565.10	8.8	15.4
Niagara Falls, N.Y.	197.6	8.1	50,760	1,824.00	7.9	6.1
Poughkeepsie, N.Y.	165.5	19.0	35,000	1,134.52	11.2	6.3
Rochester, N.Y.	155.3	14.6	295,750	1,170.24	12.5	5.2
Schenectady, N.Y.	140.2	17.2	88,723	937.56	17.8	6.4
Syracuse, N.Y.	164.0	14.1	171,717	1,193.12	19.4	6.0
Troy, N.Y.	159.7	10.9	72,013	914.23	15.5	6.2
Utica, N.Y.	182.2	8.8	94,156	736.83	11.2	6.7
Watertown, N.Y.	169.3	5.7	31,285	785.91	12.9	4.7
Yonkers, N.Y.	168.1	7.5	100,176	1,589.51	15.8	9.7
Akron, Ohio	154.8	12.9	208,435	1,367.41	7.5	6.5
Canton, Ohio	150.4	9.6	87,091	1,531.79	8.9	5.0
Cincinnati, Ohio	134.8	8.8	401,247	1,771.77	13.8	6.4
Cleveland, Ohio	150.2	21.1	796,841	1,700.59	11.6	6.8
Columbus, Ohio	128.1	15.8	237,031	1,406.50	19.0	4.6
Dayton, Ohio	130.7	14.7	152,559	1,371.38	13.8	4.5
Hamilton, Ohio	164.0	11.7	39,675	1,288.49	10.2	4.6
Lima, Ohio	139.6	9.8	41,326	1,132.83	13.1	4.3
Lorain, Ohio	183.8	6.0	37,295	1,463.65	13.3	5.7
Newark, Ohio	147.2	8.5	26,718	1,211.87	14.6	3.9
Toledo, Ohio	137.9	12.9	243,164	1,471.82	11.6	4.9
Youngstown, Ohio	187.1	7.9	132,358	1,718.21	12.3	5.5
Zanesville, Ohio	153.3	7.2	29,569	1,172.54	11.2	4.0
Portland, Oregon	125.4	6.2	258,288	1,931.32	22.9	4.7
Allentown, Penn.	160.6	18.3	73,502	840.22	10.8	4.8
Altoona, Penn.	178.1	25.4	60,331	989.63	14.4	4.8

TABLE 19 (Continued)

DATA FOR CITIES USED IN PARTIAL CORRELATION STUDY

(This table is discussed on pp. 150–156)

City	Birth rate B	Density A	Population P	Wealth W	School attendance 18–20 S	House density D
Easton, Penn.	165.9	15.1	33,813	$1,164.58	13.3	4.4
Erie, Penn.	188.3	18.7	93,372	773.96	14.6	5.4
Harrisburg, Penn.	124.8	19.7	75,917	1,119.02	15.4	4.5
Johnstown, Penn.	234.3	18.1	67,327	1,078.69	9.8	5.4
Lancaster, Penn.	191.4	20.0	53,150	866.60	11.9	4.4
McKeesport, Penn.	210.9	20.3	46,781	984.95	11.9	6.0
New Castle, Penn.	188.7	7.5	44,938	878.74	13.2	4.9
Norristown, Penn.	181.1	14.0	32,319	865.43	9.2	5.4
Philadelphia, Penn.	163.8	20.9	1,823,779	1,419.36	8.7	5.2
Pittsburgh, Penn.	175.2	22.8	588,343	1,465.25	12.7	6.3
Reading, Penn.	162.3	17.5	107,784	864.07	9.1	4.7
Scranton, Penn.	163.3	11.0	137,783	1,060.46	9.9	5.8
Wilkes-Barre, Penn.	220.6	22.5	73,833	1,451.48	14.0	5.5
Williamsport, Penn.	192.1	7.8	36,198	891.72	13.3	4.5
York, Penn.	166.5	21.2	47,512	859.31	10.2	4.4
Ogden, Utah	220.9	3.0	32,804	1,075.45	19.4	5.1
Salt Lake City, Utah	188.4	3.5	118,110	1,696.71	23.6	5.0
Bellingham, Wash.	149.6	2.1	25,585	1,102.88	23.7	4.3
Everett, Wash.	131.6	5.8	27,644	1,032.34	17.0	4.5
Seattle, Wash.	119.6	8.1	315,312	1,630.88	22.9	5.2
Spokane, Wash.	152.0	4.2	104,437	1,472.05	27.5	4.7
Tacoma, Wash.	150.6	3.8	96,965	1,277.86	18.1	4.5
Green Bay, Wis.	215.6	3.7	31,017	1,121.72	14.5	5.2
Kenosha, Wis.	176.2	10.4	40,472	1,085.77	10.6	6.4
La Crosse, Wis.	194.8	4.8	30,421	1,032.47	24.0	4.4
Madison, Wis.	154.6	9.0	38,378	1,992.81	35.3	5.1
Milwaukee, Wis.	157.6	27.5	457,147	1,394.26	14.4	6.8
Oshkosh, Wis.	164.9	6.2	33,162	1,089.67	19.0	4.4
Racine, Wis.	167.4	14.2	58,593	1,308.46	9.0	5.6
Superior, Wis.	170.6	1.7	39,671	1,154.32	18.6	5.4

TABLE 20

BIRTH RATES OF WHITES, PER 1,000 ENUMERATED FEMALE POPULATION, BY COUNTRY OF BIRTH IN THE REGISTRATION AREA AND EACH REGISTRATION STATES: 1920 *

(Rates are shown in italics when the number of births is less than 5)
(This table is discussed on p. 159)

Area	Rate per 1,000 enumerated female population						
	Country of birth						
	United States	Canada	Denmark, Norway, and Sweden	England, Scotland, and Wales	Ireland	Italy	Other foreign coun-tries
The registration area	42.8	47.3	39.4	38.2	41.5	160.0	85.2
California	34.7	25.8	33.0	33.8	34.5	92.1	73.7
Connecticut	31.2	55.8	44.9	36.7	39.0	177.2	117.2
Dist. of Columbia .	33.9	23.4	43.0	32.9	31.2	137.9	68.2
Indiana	43.8	28.3	34.9	41.6	29.2	137.8	83.0
Kansas	46.4	15.5	20.6	18.8	14.1	96.1	58.8
Kentucky	55.1	12.8	44.6	21.3	13.1	124.3	29.6
Maine	41.3	72.1	41.9	42.7	48.9	231.2	103.9
Maryland	47.1	44.8	52.8	43.3	28.2	160.0	72.9
Massachusetts	33.2	54.7	42.7	42.0	50.1	175.7	116.9
Michigan	47.7	41.2	37.5	52.3	35.3	203.2	98.8
Minnesota	48.5	29.4	41.9	43.9	26.1	166.3	63.5
Nebraska	49.8	12.0	33.3	25.2	21.0	180.4	52.8
New Hampshire ...	37.0	71.4	34.9	34.6	34.5	176.4	130.6
New York	33.5	39.0	41.5	36.0	42.6	150.8	72.9
North Carolina	64.2	47.5	78.4	48.2	33.1	52.3	92.0
Ohio	39.9	32.7	41.3	35.8	31.4	178.0	82.5
Oregon	39.5	33.3	37.6	41.5	27.0	112.5	51.6
Pennsylvania	42.0	40.5	40.5	36.0	39.2	188.8	118.1
South Carolina	59.1	51.7	*30.8*	70.4	*19.1*	97.2	72.5
Utah	64.5	57.3	46.4	44.5	42.4	151.5	110.9
Vermont	39.1	61.1	35.0	43.7	24.8	107.8	144.4
Virginia	56.7	46.3	54.7	47.6	34.9	124.2	90.6
Washington	41.0	36.6	43.4	40.3	40.8	109.0	57.3
Wisconsin	45.4	25.7	32.8	28.7	19.4	191.2	51.1

* Taken from (p. 10) Birth Statistics for the Birth Registration Area of the United States, 1920. Washington (Government Printing Office), 1922.

TABLE 21

AVERAGE FREQUENCY OF COITUS PER MONTH
(This table is discussed on pp. 185–186)

Times per month	Number of cases in the specified decades													
	Under 20		20–29		30–39		40–49		50–59		60–69		70–79	
	Absolute	Per cent	Absolute	Per cent	Absolute	Per cent	Absolute	Per cent	Absolute	Per cent	Absolute	Per cent	Absolute	Per cent
0– 4	99	75.6	68	31.9	49	19.8	64	25.4	101	40.9	131	68.6	72	91.1
5– 9	11	8.4	48	22.5	75	30.4	81	32.1	86	34.8	35	18.3	4	5.1
10– 14	6	4.6	40	18.8	56	22.7	50	19.8	28	11.3	18	9.4	3	3.8
15– 19	1	0.8	18	8.5	26	10.5	25	9.9	16	6.5	2	1.0	..	....
20– 24	8	6.1	17	8.0	16	6.5	14	5.6	5	2.0	3	1.6	..	....
25– 29	1	0.8	4	1.9	6	2.4	6	2.4	3	1.2	..	....	..	....
30– 34	3	2.3	9	4.2	14	5.7	9	3.6	6	2.4	1	0.5	..	....
35– 39	2	1.5	3	1.4	1	0.4	..	....	...	....	...	....	..	....
40– 44	..	....	1	0.5	..	....	..	....	...	....	...	....	..	....
45– 49	..	....	..	....	..	....	1	0.4	...	....	...	....	..	....
50– 54	..	....	1	0.5	..	....	1	0.4	1	0.4	...	....	..	....
55– 59	..	....	..	....	..	....	..	....	1	0.4	...	....	..	....
60– 64	..	....	2	0.9	2	0.8	1	0.4	...	....	1	0.5	..	....
65– 69	..	....	..	....	..	....	..	....	...	....	...	....	..	....
70– 74	..	....	..	....	1	0.4	..	....	...	....	...	....	..	....
75– 79	..	....	..	....	..	....	..	....	...	....	...	....	..	....
80– 84	..	....	..	....	..	....	..	....	...	....	...	....	..	....
85– 89	..	....	..	....	..	....	..	....	...	....	...	....	..	....
90– 94	..	....	..	....	..	....	..	....	...	....	...	....	..	....
95– 99	..	....	..	....	..	....	..	....	...	....	...	....	..	....
100–104	..	....	1	0.5	1	0.4	..	....	...	....	...	....	..	....
105–109	..	....	..	....	..	....	..	....	...	....	...	....	..	....
110–114	..	....	1	0.5	..	....	..	....	...	....	...	....	...	....
Totals	131	100.1	213	100.1	247	100.0	252	100.0	247	99.9	191	99.9	79	100.0

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